Workshop Proceedings
Atlantic Beach, NC
February 10-12, 2004

DCERP
Defense Coastal/Estuarine Research Program

DoD EPA DOE SERDP
Strategic Environmental Research and Development Program

NAVFAC
Naval Facilities Engineering Command
Engineering Service Center

CAMP LEJEUNE

HydroGeoLogic, Inc.

July 22, 2004
(rev. February 2005)

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE **FEB 2005**	2. REPORT TYPE	3. DATES COVERED **00-00-2005 to 00-00-2005**

4. TITLE AND SUBTITLE **DCERP Defense Coastal/Estuarine Research Program Workshop Proceedings**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Facilities Engineering and Expeditionary Warfare Center,1000 23rd Avenue,Port Hueneme,CA,93043**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**55**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

ACKNOWLEDGEMENTS

This report summarizes the results of a workshop sponsored by the Department of Defense's (DoD) Strategic Environmental Research and Development Program (SERDP). With the assistance vision and leadership from Dr. Mary Barber (SERDP Scientific Advisory Board Representative), the workshop sought to design an ecosystem management research program for the New River Region of North Carolina.

Many individuals contributed to the development and execution of this workshop. These individuals include representatives of Marine Corps Base Camp Lejeune (the host installation for this new research program). Specifically the efforts and support of Mr. John Townson, Mr. Daniel Egge, Ms. Julie Shambaugh, Mr. Carmen Lombardo, Mr. Duncan Dawkins, Mr. Scott Brewer, and Mrs. Loretta Wright are of note. Numerous others were invaluable in their coordination efforts, and in communicating Camp Lejeune's unique natural resources and mission requirements.

Further, Ms. Leslie Karr (Naval Facilities Engineering Service Center), as well as Mr. Peter Swiderek, Mr. William Goran, and Mr. David Price (who offered insight from the ongoing SERDP Ecosystem Management Project [SEMP] at Fort Benning), also helped make this workshop a success. SERDP also acknowledges the assistance of various individuals from HydroGeoLogic, Inc. including Ms. Alison Dalsimer, Ms. Alicia Shepard, and Ms. Susan Walsh, who facilitated developmental activities for the workshop and the production of this report.

Most importantly, we wish to acknowledge the input of workshop participants—renowned experts in the field of ecosystem management—who provided the scientific foundation and recommended future research priorities for what is to become SERDP's Defense Coastal/Estuarine Research Program (DCERP). Attributions appear in Appendix 2.

Editor's Note: For programmatic reasons, in December 2004, the initiative name was changed from Defense Coastal/Estuarine Research Center (DCERC) to Defense Coastal/Estuarine Research Program (DCERP). This document was updated to reflect that change in February of 2005.

LIST OF ACRONYMS

AUV - autonomous underwater vehicles

BMPs - best management practices

BST/MST- bacterial source tracking/microbial source tracking

CLION - Camp Lejeune Integrated Operations Network

DCERP - Defense Coastal/Estuarine Research Program

DEEMRC - Defense Estuarine Ecosystem Management Research Center

DoD - Department of Defense

ECMI – Ecosystem Characterization and Monitoring Initiative

HABs – harmful algal blooms

ICW - Intracoastal Waterway

INRMP - Integrated Natural Resources Management Plan

LLP - longleaf pine

NGO - non-governmental organization

NPS - non-point source (usually with respect to pollution)

PAHs – polynuclear aromatic hydrocarbons

RCW - red-cockaded woodpecker

R&D - research and development

SAV - submerged aquatic vegetation

SEMP - SERDP's Ecosystem Management Project

SERDP - Strategic Environmental Research and Development Program

SOD - sediment oxygen demand

TES - threatened and endangered species

TMDL - total maximum daily load

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

Page

TABLE OF CONTENTS (continued)

This document presents a summary of results from a workshop sponsored by the Strategic Environmental Research and Development Program (SERDP), originally entitled Defense Estuarine Ecosystem Management Research Center (DEEMRC), and held 10-12 February 2004 at the Sheraton Oceanfront Hotel in Atlantic Beach, North Carolina. Upon further consideration, the initiative's name was changed to the Defense Coastal/Estuarine Research Program (DCERP).

SERDP is the Department of Defense's (DoD) corporate environmental research and development (R&D) program, planned and executed in full partnership with the Department of Energy and the Environmental Protection Agency, with participation by numerous other federal and non-federal organizations. DoD's environmental concerns may be viewed in terms of operational and/or cost impacts to its primary mission of maintaining military readiness for national defense. SERDP's Conservation Thrust Area supports R&D efforts to (1) sustain the use of DoD's lands, estuaries, ocean and air space; (2) protect its valuable natural and cultural resources for future generations; (3) comply with legal requirements; and (4) provide compatible multiple uses of its resources.

1.0 BACKGROUND

1.1 ECOSYSTEM MANAGEMENT WITHIN DOD

The DoD serves as guardian for approximately 25 million acres of land, large offshore operating areas, and the surrounding airspace. DoD is responsible for protecting more threatened and endangered species (TES) per acre than any other federal land manager. Additionally, DoD is committed to the protection of cultural artifacts and sensitive habitats that exist on U.S. military installations. These diverse and complex systems must be managed wisely to allow for realistic military testing and training activities, while simultaneously ensuring environmental protection.

Since the 1990s, DoD developed a wide range of policy guidance that established a requirement for managing ecosystems rather than single species.[1] This approach broadens the scope from site-specific assessments to a regional, or ecosystem-based, focus. Ecosystem management is one component of DoD's ongoing effort to achieve sustainability in minimizing the impact of military training so that installations can continue to provide realistic training. Given that the U.S. military lives and trains in nearly every terrain, climate, and vegetative context across the nation, this represents a significant challenge.

1.2 ECOSYSTEM MANAGEMENT WORKSHOP, 1997

In 1997, SERDP sponsored a major workshop focusing on management-scale ecosystem research. The workshop hypotheses, supported by participants at the conclusion, were that:

1. It is possible to do ecosystem-scale research on military lands while operations are ongoing;

[1] See DoDI 4715.3 Environmental Conservation Program and, more specifically, UDSD(ES) policy on Implementation of Ecosystem Management in the DoD, 8 August 1994.

2. This research would be supportive of specific military missions and to overall military mission readiness;
3. This research would advance ecosystem science in general and therefore be of interest to the ecological scientific community; and
4. This research would improve the management of the ecosystems on DoD lands and waters, including conservation of biological resources, compliance with environmental laws and regulations, and restoration of disturbed areas.

A wide range of important findings resulted from the workshop—these may be viewed within the SERDP-ESTCP Online Library at http://docs.serdp-estcp.org/viewfile.cfm?Doc=CS%2D1114%2DTR%2D97%2Epdf. In addition, the following four central themes emerged independently from the workshop's breakout sessions:

- **Ecosystem Indicators:** There is a need to develop indicators of ecosystem health. These indicators would be designed to provide early warning of biological deterioration within the ecosystem.

- **Thresholds:** There exist thresholds within natural systems that represent "break points." A threshold is the point at which any further deterioration in ecosystem condition will result in the system being unable to return to its initial state without significant intervention. Determining these thresholds is critical to management of ecosystems that are routinely subjected to the stress and disturbance of military operations.

- **Biogeochemical Cycles:** The regulation and control of nutrients and other chemicals moving through an ecosystem exert fundamental control over the trajectory of the ecosystem. Understanding the roles of these natural cycles and the impacts of their manipulation is necessary for conducting active, adaptive management.

- **Spatial and Temporal Scales:** Biogeochemical processes occur at all scales from microscopic to ecosystem to regional. Understanding the interaction between processes that occur at myriad scales is essential to understanding how an ecosystem functions over time.

To implement the 1997 workshop findings, SERDP developed an initiative known as the SERDP Ecosystem Management Project (SEMP). Detailed information about SEMP can be found at http://www.cecer.army.mil/KD/SEMP/index.cfm?chn_id=1063.

SEMP's objectives are four-fold:

1. To address DoD requirements and opportunities in ecosystem management research.
2. To establish a long-term research site(s) on DoD lands for relevant ecosystem research.
3. To conduct ecosystem research and monitoring activities relevant to DoD requirements and opportunities.
4. To facilitate the integration of research findings and results into DoD ecosystem management practices.

It was determined that SEMP would initially be implemented at an inland installation to examine issues associated with terrestrial ecosystems. Based on its location in the southeastern United States, significant mission activities, and proactive approach to ecosystem management, SEMP was established at Fort Benning, Georgia, in 1999. SEMP includes an extensive monitoring system and a series of research projects focused on the themes that emerged from the workshop. It was originally envisioned that there would be at least one other site where SEMP would be implemented, and that this second site would be in an estuarine environment.

1.3 ESTUARINE RESEARCH SITE SELECTION

In 2002, Marine Corps personnel approached SERDP requesting assistance in dealing with issues concerning the management of natural resources on Marine Corps Base Camp Lejeune, North Carolina (Camp Lejeune). After an informal survey of military installations located in estuarine environments, it was decided to pursue establishing the second SEMP site at Camp Lejeune. The main reasons for selecting this site include that:

1. The New River watershed is relatively small and, therefore, tractable.
2. The Marine Corps owns a substantial portion of the estuary shoreline.
3. There is a unique barrier island/coastal dune system within the installation.
4. The variety of ongoing military operations enables researchers to examine training impacts on a broad range of ecosystems from upland to aquatic to coastal.

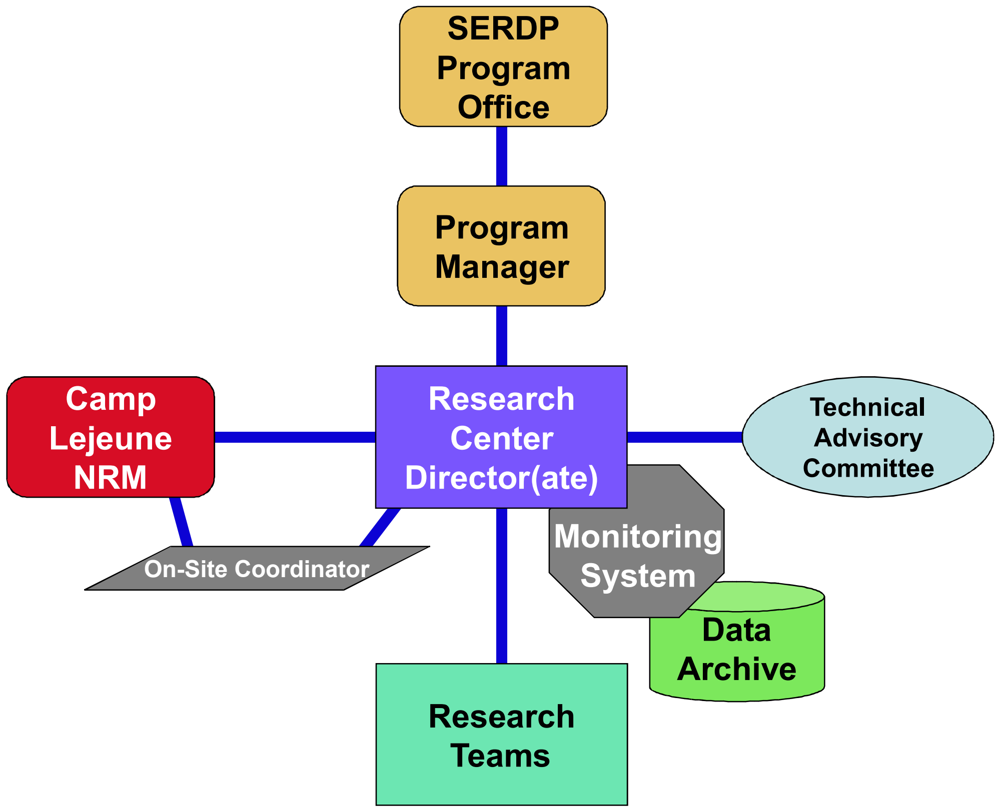
In 2003, discussions began with the Marine Corps concerning establishment of the second site at Camp Lejeune. For a variety of programmatic reasons, SERDP decided to establish and manage this second site separate from the existing SEMP management structure. While the broad goals and objectives for the second site are the same as they are for SEMP, this project was named the DCERP to differentiate it from the Fort Benning SEMP. The overarching federal management for the DCERP was awarded to the Naval Facilities Engineering Service Center (NFESC).

1.4 PROJECT STRUCTURE

Based on recommendations from the SERDP Scientific Advisory Board, DCERP will be structured as a research center. Several models for research and technology centers, some of which are based on the National Science Foundation model, have been considered. At a minimum, there will be a Center Director or Directorate selected through a full and open competition. The Center Director(ate) will be responsible for coordinating day-to-day operations and ongoing projects, and for the quality of science pursued.

Like SEMP, the DCERP is expected to develop a baseline monitoring system over much, if not all, of the base and surrounding watershed, and to manage individual research efforts designed to answer specific questions. Due to the presence and availability of the data from the monitoring system, as well as the infrastructure that will be installed, it is envisioned that Camp Lejeune will become a platform for a variety of other ecological efforts. SERDP plans to make a 10-year commitment to the DCERP, as it did with SEMP.

DCERC Management Structure



1.5 DEVELOPMENT TIMELINE

Lessons learned from the establishment of the SEMP program led to the development of an expanded timeline for establishing the DCERP. The timeline developed at the workshop is as follows:[2]

- **FY 2004**
  - Workshop to Identify Research Questions and Monitoring Needs
  - Solicitation for Center Director(ate)
  - Design of Monitoring System/Data Repository

- **FY 2005**
  - Installation of Monitoring System
  - Solicitation/Development of Research Projects

- **FY 2006**
  - Monitoring System/Data Repository Operational
  - Research Projects Commence

[2] Due to funding restrictions, implementation of this timeline has since been further expanded.

2.0 WORKSHOP AGENDA[3]

2.1 WORKSHOP GOALS

Camp Lejeune is the Marine Corps' major installation in the eastern United States. As such, it is imperative that this asset be managed in a manner that will ensure its sustainability and continued use in perpetuity. The goal of this initial formative workshop was to facilitate the launch of an estuarine ecosystem research center at Camp Lejeune. To accomplish this, participants were to develop and articulate research questions and monitoring needs pertinent to the effective management of the New River watershed and long-term sustainability of Camp Lejeune ecosystems. Workshop objectives were stated as follows:

1. Determine the state of the science for estuarine ecosystem management.
2. Based on the state of the science, determine current gaps in the scientific knowledge.
3. Having identified knowledge gaps, determine the research topics, in rough priority, that should be addressed in the context of DoD missions and needs.
4. Develop the initial design of the components of a long-term monitoring plan.

To achieve these objectives, the workshop was designed to maximize the amount of time available for group discussions and to gain insight into the current research being undertaken in estuaries in general and more importantly in the New River and surrounding estuaries (i.e., the Neuse River and Cape Fear River estuaries). The workshop began with an introductory plenary session and a field trip to Camp Lejeune. This was followed by two breakout sessions to address research and monitoring issues, respectively, and a closing summary session in which participants discussed the overall context of the workshop and proposed work.

2.2 PARTICIPANTS[4]

SERDP ensured that participants represented a diverse group of knowledgeable experts who could provide the broad technical basis for what will become the DCERP's scientific platform. A total of 42 invitees, including representatives from major universities, laboratories, and non-governmental organizations (NGOs) working in the field, were selected to participate in the workshop. The invited attendees also included several representatives from Fort Benning who have been integrally involved in SEMP, and representatives from Camp Lejeune.

2.3 ESTABLISHING A COMMON GROUND

The first day of the workshop was devoted to providing the attendees with background and contextual information. While many participants were familiar with the New River and with Camp Lejeune, others were not. Similarly, many of the participants were unfamiliar with the requirements of military operations and the constraints that environmental regulations can place upon those operations.

---

[3] See Appendix 1 for the workshop agenda.
[4] See Appendix 2 for the workshop participants.

2.3.1 Plenary Session

Mr. Bradley Smith, SERDP's Executive Director, provided an overview of the SERDP program, the genesis of the SEMP program, and the selection of Camp Lejeune as the second SEMP site. Mr. Smith also detailed the workshop's goals and expected outcomes.

Brigadier General Dickerson, Commanding General, Camp Lejeune, welcomed attendees, pointing out that the Marine Corps is a good steward of the environment and that personnel at Camp Lejeune hold themselves to a high standard. He noted that the installation is a launching pad for force protection, and stated that its boundaries harbor eight endangered species, numerous ranges, and shorelines. He concluded by highlighting the strong need to balance the installation's training and environmental stewardship missions.

Lieutenant Colonel Gary Oles, Director of the Range Control Division at Camp Lejeune, provided an overview of existing range requirements, and communicated the importance of realistic training scenarios. He stressed the critical role that timely notification, scheduling, and co-use opportunities will play in coordinating the research and monitoring activities under DCERP with ongoing training exercises.

Dr. Robert Holst, Conservation Program Manager for SERDP, provided an overview of related projects and efforts within SERDP, including the SEMP.

Mr. Peter Swiderek, Conservation Branch Chief at Fort Benning, shared his experiences concerning the benefits, costs, and lessons learned related to the development and implementation of SEMP at Fort Benning. Specifically, Mr. Swiderek stated that a major benefit of having SEMP at Fort Benning is that the research supports compliance and lends regulatory credibility to the installation. On the cost side of the equation, Mr. Swiderek noted that program management, coordination efforts, and support services have been time-consuming and resource-intensive. Two of the lessons learned at Fort Benning include the need for identifying data gaps early in the planning process and the importance of coordinating with installation personnel regarding the location of research sites and timing of research activities. He emphasized the critical role that the SEMP On-Site Coordinator plays in scheduling the research and monitoring activities that occur on the installation, and in communicating with principal investigators and other members of the myriad research teams. He finished by noting that results from Fort Benning are currently being transitioned to other installations along the Fall Line.[5]

2.3.2 Field Tour of Camp Lejeune

In order to better understand the installation, its natural resource base, and the ways in which personnel address both environmental and mission needs, workshop participants spent the afternoon of the workshop's first day touring Camp Lejeune. The installation's environmental staff selected three locations of interest, and provided on-site presentations at each.

[5] The Fall Line Sandhills separate the Piedmont from the Coastal Plain in Georgia northeast into North Carolina. Several military reservations are found along the Fall Line Sandhills.

The three sites illustrated the diversity of ecosystems found on Camp Lejeune. They included a longleaf pine (LLP) stand in which several red-cockaded woodpecker (RCW) clusters have been established, the coastal dunes adjacent to the primary landing zone for amphibious assaults, and the New River estuary itself.

Feedback on the post-workshop evaluation forms indicate that the overwhelming majority of participants found the field tour to be highly beneficial in helping them understand what Camp Lejeune offers in the way of resources, and in significantly improving their understanding of the complexities and potential conflicts that resource managers face when trying to balance readiness and mission requirements with conservation needs.

2.3.2.1 Longleaf Pine/Red Cockaded Woodpecker Area

This site, located near one of the primary impact areas, is faced with problems associated with long-term establishment and maintenance of suitable RCW habitats that require pine stands free of undergrowth. This requires continual and intensive maintenance either by conducting prescribed burns on a three to five year rotation, which also helps induce LLP growth, or by periodic roller chopping or bush-hogging. In addition to trying to increase available LLP stands, Camp Lejeune natural resource personnel have installed numerous artificial bird houses to hasten the establishment of and expand existing RCW clusters.[6]

Despite the time and intensive management required to grow LLP, installation personnel recognize that improving and expanding RCW habitat is the only way to ensure the species' success and, ultimately, to alleviate the current training restrictions associated with the protection and recovery of the RCW placed on the installation by the U.S. Fish and Wildlife Service.

Explanations provided at this site provided a good example for the processes and requirements involved in integrating military training, protecting endangered species, and conducting appropriate fire and forest management. All of these activities are required under the Biological Opinion of the Endangered Species Act in order to reestablish the RCW.[7] For a copy of the

2.3.2.2 Onslow Beach

Camp Lejeune manages 14 miles of beach along the Atlantic Ocean, which includes five miles of available training coastal beach—more than on any other military installation in the country. To maximize beach usage and meet competing and sometimes conflicting goals, base personnel have divided the installation's shoreline into three segments: training and impact, recreational, and off-limits (primarily due to the presence of TES and species of concern, but also to preserve the character of the frontal dune system). The primary staging area and other small training zones are located approximately 200 meters behind the dunes.

---

[6] RCWs will nest in loblolly pine stands; however, they prefer and have better reproductive success in old-aged longleaf pines.

[7] USFWS Biological Opinion, "Camp Lejeune's Mission Compatible Plan for the Comprehensive Long Range Management of the Red-Cockaded Woodpecker and Biological Assessment on Operations at Marine Corps Base, Camp Lejeune, North Carolina," November 30, 1999. Available on password protected DENIX site at https://www.denix.osd.mil/denix/DOD/Working/DCERP/Documents/USFWSBioOpWoodpecker.pdf.

During turtle nesting season, mid-May to mid-August, the near-shore dunes of the training and impact beach provide primary nesting locations for the endangered loggerhead and green sea turtles. During this period, installation personnel implement an intensive sea turtle monitoring, nest relocation and protection program so that amphibious landings and other training activities can be conducted without impacting protected species. Because the beach is so intensively monitored, nest relocation occurs within 12 hours of a turtle laying its eggs. Equally important, nest-free training areas are maintained by base personnel so that trainers do not have to work around active turtle nests. Training activities that occur on this beach include heavy use by landing craft. Not surprisingly, the dunes within the training landing zone suffer erosion due to their constant use as compared to the more protected dunes in the non-training areas.

2.3.2.3 New River Estuary

This stop demonstrated that Camp Lejeune has training areas on both sides of the New River estuary, with the cantonment area located on the southeast side and the airfield located on the northern side.[8] In part to alleviate pollution in the New River, Camp Lejeune recently combined all of its wastewater treatment plants into a single, more efficient treatment plant. As a result, effluent nutrient load has been significantly reduced, resulting in a substantive reduction of nutrient input throughout the estuary.

2.4 FORMATION OF BREAKOUT GROUPS

The primary objective for this initial formative workshop was to develop a roughly prioritized research agenda and monitoring plan for the DCERP for the next four to five years. Participants were asked to discuss the state of the science for estuarine ecosystem management as a basis for determining gaps in current scientific knowledge, identify and roughly prioritize research needs, and develop the initial design for a monitoring plan for the New River watershed. To do this, attendees participated in one of three breakout groups within both the research and monitoring topic areas.

Research Breakout Groups	Monitoring Breakout Groups
Aquatic Habitats	Estuarine Systems
Terrestrial Habitats	Terrestrial Systems
Water Quality	Coastal Systems

3.0 RESEARCH BREAKOUT GROUPS

The research breakout groups were tasked to identify ecosystem research needs for the area in and surrounding Camp Lejeune. The Aquatic Habitat breakout group focused on the aquatic regions from the littoral zone (extending to approximately 10 meters depth in the ocean) into the New River estuary and its tributaries; the Terrestrial Habitat breakout group focused on regions of the installation and surrounding environs that may affect the ecosystem(s) of the immediate area; and the Water Quality breakout group discussed issues relevant to the estuary, its

[8] The cantonment area refers to living/housing/office areas (i.e., accommodations).

tributaries, and the near coastal ocean. The research breakout groups also were tasked to examine issues on both a temporal and spatial scale, and to include a rough priority ranking or tier system for the identified research needs. Prioritizations by breakout group are presented in Appendix 3.

3.1 AQUATIC HABITAT

The Aquatic Habitat breakout group was tasked to address research issues relating to aquatic ecosystems. The water quality (i.e., chemical and physical) aspects of these issues were addressed by a separate breakout group. It was recognized that many of the issues and needs would be very similar between this group and the other two (terrestrial and water quality) as the aquatic systems are recipients of, and therefore directly affected by, land-based activities.

The group identified the following habitats to consider in its discussions:

- Stream and tributary components (including seeps, floodplains, and non-tidal wetlands)
- Intertidal wetlands
- Mudflats and other intertidal regions
- Shallow, subtidal regions (including submerged aquatic vegetation, macroalgae and microalgae)
- Estuarine and riverine water column
- Beach and dunes
- Surf zone
- Nearshore (including pelagic and benthic)

During initial discussions, the group expressed the need to develop a baseline for assessing the impacts of disturbance within the New River/Camp Lejeune region. That baseline would necessarily encompass both historical information and current assessments. They stressed the use of paleo-disciplines, techniques, and research to determine prehistoric conditions. Mining of historic national, state, and local data sets (e.g., water quality, fisheries records, and natural resources) was considered essential. These data sets would be used to identify ecological change and trends in the aquatic habitat over different scales. The scales needed to describe these trends range from the New River estuary to the entire region. An assessment of present-day ecosystem structure and function also would be required. To accomplish this, areas lacking recent inventories must be identified. With complete inventories, the abiotic and biotic interactions and feedback loops within the ecosystem can be determined. The group stressed that aquatic environments are dynamic and responsive to interacting and synergistic stressors. Synthetic modeling could be used to identify the roles of both natural and anthropogenic forces in ecosystem change. In this process, it is important to recognize that both natural (e.g., hurricanes) and anthropogenic (e.g., military training) activities are potentially responsible for the changes that may be identified. The results from these analyses would feed into the design of the monitoring system and help identify appropriate timescales over which to measure change. Below are topical categories addressed by the Aquatic breakout group, including lists of recommended research objectives and/or projects.

3.1.1 Nutrients, Particulates, Contaminants, Pathogens

These classes of constituents can be found dissolved or suspended in the water column. They are transported by the water, and have a variety of effects on the aquatic ecosystems in which they occur. There were a number of research issues identified that are common to each of these constituents.

- Define the manner in which nutrients, particulates, contaminants, and pathogens (the constituents) cycle in the environment, accounting for the sources of input; impacts of physical, chemical, and geological processes; transport; fate; and spatial and temporal distributions.
- Determine the ecological impacts of chronic versus episodic inputs of the constituents. Specifically, investigate the roles of:
    - Varying frequencies and intensities of disturbance
    - Storm water dynamics
    - Impermeable surfaces and mitigation buffers
- Assess the impacts of the land use change and military operations that follow on the input, transport, and fate of the constituents:
  - Amphibious vehicle traffic on the water and on the beach
  - Tracked and wheeled military vehicle traffic
  - Small, medium, and large caliber live fire
  - Burning
  - Clear cutting
  - Channelization
  - Salt marsh creation
- Evaluate the impacts of changes in ecosystem management practices on the input, transport, and fate of the constituents.
- Determine the impacts of changes in the input and cycling of the constituents to the composition and activity of the micro-algal and higher plant communities, as well as to the higher trophic levels.
- Establish a baseline and metrics for the constituents and their cycles.

3.1.2 Indicators

Indicators of environmental health are rapidly developing as tools for monitoring and managing trends in community structure and function. For the New River estuary, indicators need to be identified and their ecology studied.

- Identify indicators of physical/chemical change and ecological stress.
- Develop and apply indices of biodiversity and abundance to measuring changes in the food web and community structure.
- Couple biological and physical-chemical indicators with remote sensing to facilitate ecosystem-level assessments of condition and change.

3.1.3 Thresholds

In addition to functioning as indicators, thresholds serve two broad purposes. The first is as a tool for determining and managing acceptable levels of disturbance and stress within an ecosystem. To do this, it is necessary to establish thresholds for physical, chemical, and biotic drivers of change to the aquatic environment (e.g., burning, runoff, resuspension). Specifically, there is a need to investigate thresholds:

- Related to changes in the fundamental state of the aquatic environment that affect community structure and function; and
- To know whether the carrying capacity and tolerance of a system to a stressor or pollutant is exceeded to the extent that ecosystem function and service are significantly altered and/or impaired (i.e., causing a state change).

The second purpose is to ensure compliance with regulatory standards, specifically Total Maximum Daily Loads (TMDL). With respect to these thresholds, researchers need to:

- Define the amount of a specific pollutant that a stream, lake, estuary, or other body of water can receive without violating state TMDL standards;
- Assign responsibility for reducing pollution among both point and non-point sources once a TMDL is established; and
- Determine such values for the New River estuary.

3.1.4 Threatened, Endangered, and At-Risk Species

Eight federally listed threatened and endangered species (TES) are found at Camp Lejeune. Of these, the green sea turtle (*Chelonia mydas*), loggerhead sea turtle (*Caretta caretta*), seabeach amaranth (*Amaranthus pumilus*), piping plover (*Charadrius melodus*), American alligator (*Alligator mississippiensis*), and American bald eagle (*Haliaetus leucocephalus*) are associated with aquatic habitats. There are also numerous state-listed and federal species of concern. The endangered species program at Camp Lejeune includes conservation, protection, and management of all these species.

- In addition to TES, identify at-risk species and their habitats.
- For species identified, determine the extent and quality of their habitat.
- Identify threats to at-risk species using a habitat-based and holistic approach.

3.1.5 Physical Disturbance Processes

Physical disturbance processes, whether natural or anthropogenic, in the coastal areas of Camp Lejeune are evident but not well-understood. Since these coastal areas fill critical roles for both military training and the ecosystem, there is a need to understand these processes in order to develop and implement informed management approaches.

- Identify the physical disturbance processes that impact the ecosystem, taking into account natural sediment dynamics. Consider the following processes:

    - Storms, hurricanes, flooding
    - Beach nourishment/erosion
    - Upland erosion
    - Vehicle traffic
    - Dredging and channelization
- Evaluate the impacts of these physical disturbance processes on the aquatic habitat for both the vertebrate and benthic community.
- Investigate the impacts of these physical disturbance processes on the physical structure of the beach, and the biotic communities that inhabit it.

3.1.6 Hydrodynamics

Within the New River estuary, hydrodynamics play a critical role in the relationship between external inputs and stressors, internal biogeochemical cycling, sediment/water column interactions, and ecosystem response to stressors. An understanding of hydrodynamics is essential to determining the exchange and mass balance of constituents (i.e., nutrients, particulates, contaminants, pathogens) between the New River, coastal ocean, and atmosphere.

- Assess the long-term effects of local and regional water withdrawal on the freshwater budget.
- Determine the ecological impacts of changes in the hydrologic regime.
- Investigate the impacts of dredging and channelization on hydrodynamics.

3.1.7 Invasive Species

Invasive and/or exotic species, such as phragmites and algal blooms, in the aquatic environment pose a significant threat to native species. Harmful changes in community structure and function often result from their introduction.

- Determine the extent and distribution of exotic and/or invasive species.
- Quantify the dispersion rates of these species.
- Evaluate the impacts of these species, in terms of presence and numbers, on military operations and ecosystem structure and function.
- Identify relevant and appropriate management actions.

3.1.8 Climate Change

Global climate change is another external driver that must be considered. According to the National Academy of Sciences, the Earth's surface temperature has risen by approximately one (1) degree Fahrenheit in the last century, with an accelerated rate during the past two decades. Most of the warming over the last 50 years is directly attributable to human activities. Effects to the aquatic environment are uncertain at this point. Similarly, calculations of climate change for specific areas are less reliable than global ones, and it is unclear whether regional climate will be more variable.

- Identify the locally anticipated physical consequences of climate change (e.g., sea level rise, storm frequencies and intensities, rainfall, flooding).

- Evaluate potential impacts of these physical changes on aquatic ecosystems.

3.2 WATER QUALITY

The Water Quality breakout group was tasked to discuss issues dealing with general water quality, sediment load, eutrophication and nutrient loadings, shoreline and stream restoration, and sanitary and health-related topics. In addition to the specific research questions listed by category below, it is essential that metrics for water quality within the New River watershed and estuary be developed. Without such metrics, there will be no way to measure change. Below are topical categories addressed by the Water Quality breakout group, including lists of recommended research objectives and/or projects.

3.2.1 Sources of Nutrients and Contaminants

One of the driving forces in water quality is the introduction of compounds that are either not natural or are introduced in quantities that exceed the level that would be expected under natural conditions. Identifying these sources, measuring their inputs, and determining the impacts from these inputs is key to understanding the system. Anthropogenic sources stem from a variety of activities including military training, agriculture, forest management practices, and urbanization (waste water/sewage).

- Prescribed burns yield nutrients and other products of combustion that may affect water quality. Determine the level of nutrients and potential contaminants (including dioxin) that are released during prescribed burns.
- Non-point source pollutants (i.e., those contaminants that are diffuse in their origin and fate and therefore cannot be definitively linked to a single specific source) can be major contributors to the overall contaminant load. Develop methods for identifying and quantifying NPS contaminants. The use of markers (e.g., microbial source tracking/MST, stable isotopes, chemical markers) or other tools are possible solutions.
- Develop measures for the nutrients and contaminants released into the water as a result of military operations. Correlate the quantity and/or flux of contaminant release with types/intensity of military training and levels of activity.

3.2.2 Sediments

In-stream and river sedimentation play a major role in the quality of the estuary. In addition to increasing turbidity and burying benthic communities, sediments are often the transport mechanism for contaminants.

- Military training and construction can cause soil compaction and denude the ground. Eroded soils may then move from land into the streams and estuary. Develop methods to accurately quantify and predict the erosion caused by military operations, especially for landing craft and amphibious assault vehicles that are unique to Camp Lejeune.
- There is a need to understand the role of sediments and their interaction with, and impact on, nutrient cycling and oxygen dynamics in the water column. Potential methods to accomplish this include the use of ongoing and historic data collections to determine current patterns,

chemical loads, etc. Develop models to predict and follow these sources and their movements.
- Develop a comprehensive modeling of the hydrodynamics of the sediments, including meteorological inputs (e.g., winds and rains) and tides.
- During military training, sediments in various parts of the estuary may become disturbed. Determine the impacts, if any, of this disturbance on water quality in both the immediate vicinity and throughout the region. Develop alternative training scenarios, as appropriate, so the military can reduce sediment loading.
- Evaluate best management practices (BMPs) to determine whether the use of BMPs in training and construction areas is effective.
- Develop an inventory of contaminants carried by sediments. Following the confirmation of contaminant presence, determine the movement of each within the estuary and into the coastal zone (e.g., how long does it take for the substances to move through the system?).
- Of particular interest within the nutrients arena is nitrogen. Examine the nitrogen loading and nitrate input pulses entering New River system. A source assessment management plan should be developed for these source pulses. Determine if construction of the new waste treatment facility at Camp Lejeune has improved water quality.
- As part of the fate issue, if information is not already available, address the movement of toxic substances from sediments into the water column and their availability to biota. Consider early on the important interaction of light and nutrients, throughout the riverine, estuarine, coastal continuum.
- An overall view of the hydro/geomorphology of the sediments would be very useful to understanding the potential inputs and movement of the nutrients. Address the problems associated these inputs and movements.
- Determine the impact of translocating sediments to renourish the beach.

3.2.3 Hydrodynamics

The water portion of the water quality equation is a primary concern as it is affected by all other issues noted in this section. Water movement and flow is of great interest not only to the Marines but also to the communities up river and near the outlet to the Atlantic Ocean.

- Determine the effects of storm water runoff on water quality, including salinity. Identify management practices to mitigate these effects.
- Define the flow characteristics of the streams, tidal creeks, marshes, and mudflats in the watershed.
- Determine the tidal dynamics of the New River.
- Evaluate the potential effects, both positive and negative, of widening and/or deepening the inlet to increase the water flow into and out of the estuary.
- Determine the potential effect of sea level rise on water quality within the estuary.
- Determine the recharge rate and flow dynamics of the aquifer used for drinking water.
- Examine the quantity and quality (with respect to contaminant loading) of groundwater flow to the river.

3.2.4 Indicators

Indicators of water quality as it affects environmental health have gained increased importance recently. For the New River estuary waters, indicators need to be identified and their ecology studied. The following should be examined as potential for use as indicators:

- Invertebrates, shellfish, fish, macrophytes, and seagrasses (SAVs) as integrative environmental indicators, both in terms of ecological health and human impacts.
- Phytoplankton and benthic microalgae species, especially bloom-forming ones that occur in primary nursery areas.
- Artificial “fish” could be used as contaminate absorbing sentinels to monitor bioacumulating contaminants.

3.2.5 Sanitation

Because the New River watershed is used as a water source, a source of food, and for human recreation, sanitation of these waters and the related sediment loads is important for human and biotic health.

- Identify pathogen (BST/MST) indicators, and determine their fate across the land/water interface.
- Gulls perch on docks and other built structures around the estuary, adding to the coliform input in concentrated areas. Quantify the health risks.
- One-third of the estuary is off limits to shellfishing due to sanitation issues, and recreational swimming is restricted to certain areas. Collect epidemiological information as it relates to swimming and shellfish consumption.

3.2.6 Mitigation / Restoration

Mitigation and restoration efforts are often the key to improving overall water quality. Restoration of estuarine edges (shoreline) and remediation of contaminated sediments are seen as high priority items. Pilot project subject areas, specifically those addressing base training impacts on the estuary and focusing on NPS pollution reduction and habitat restoration, were identified as a promising means to enhance water quality. Similarly, it is well recognized that submerged aquatic vegetation (SAV) is integral to the health of the estuary.

- Identify and map existing SAV beds.
- Consider SAV restoration, especially in the vicinity of the new wastewater treatment plant.
- Investigate wave action, troop maneuvers (including the impact from new amphibious vehicles), impacts of new weapons systems, and changes in nutrient conditions on SAV.

3.3 TERRESTRIAL

The Terrestrial Research Needs breakout group was tasked to identify the research questions significant to the understanding and management of the terrestrial portions of the New River/Camp Lejeune estuarine ecosystem. The upland areas of Camp Lejeune are comprised

predominantly of longleaf pine (LLP) and loblolly pine forests. These forests are currently being intensively managed for the recovery of the red-cockaded woodpecker (RCW), a federally listed endangered species. These management practices are also designed to maintain a realistic training environment for the Marines. Consequently, much of the group's discussion revolved around understanding how to implement BMPs for RCW recovery while maintaining available training areas, as well as how to quantify the impact of those BMPs to the estuary and other ecosystems within the installation. The other topic of consideration was the barrier island/dune/beach region that is unique among DoD facilities, and is essential to amphibious training. Included in this region is the Intracoastal Waterway (ICW) that separates the barrier island from the mainland. Below are topical categories addressed by the Terrestrial breakout group, including lists of recommended research objectives and/or projects.

3.3.1 Impacts of Longleaf Pine Management

Longleaf pine forests are managed predominantly for the recovery of the RCW. The major question concerning LLP management is: What are the consequences or implications to the total biological community of managing for the RCW in LLP habitat? Prescribed burning is one of the most commonly used management protocols for LLP as LLP is a fire adapted species. However, there are many questions surrounding the use of prescribed fire.

- Determine the importance of timing versus intensity of burning, and what works best.
- Identify the effects of fire on water quality. Determine if burning releases nutrients or contaminants from the soils and if these impact sedimentation.
- Identify the effects of fire on soils.
- Evaluate the effects of fire on different ecosystems (e.g., wetlands, forest).
- Determine the effects of fire on sensitive or invasive species.
- Discern the extent and effectiveness of prescribed burns.
- Examine and articulate correlations between prescribed burns and training usage.
- Determine the extent and effects of wildfire.
- In the event of EPA burn restrictions, determine what management alternatives are available and identify the pros and cons for each alternative.

3.3.2 RCW Recovery

Camp Lejeune is required to increase its current population of RCW by over 50 percent to meet the regional recovery plan for the species. The preferred habitat for the RCW is mature LLP forests. Though the RCW will use loblolly pine trees for nesting, much of the loblolly pine forests on Camp Lejeune are senescing (aging). The goal is to transform these loblolly forests to LLP forests in the most effective manner possible while maintaining both the military mission and the RCW population.

- Develop effective methods for restoring LLP in a senescing loblolly-dominated landscape while expanding the RCW population.
- Delineate the system's unknowns and the assumptions that need to be tested (e.g., temporal and spatial scheduling of restoration).

- Develop management tools that will permit Camp Lejeune to achieve its RCW recovery and quality habitat goals while maintaining a sustainable mission. Determine the impacts of working to achieve these goals on everything else in the system.
- Evaluate and quantify the consequences to the hydrology and water table of replacing offsite (non-indigenous) pines with LLP.
- Develop measures of connectivity among RCW clusters.
- Determine the effect that degree of fragmentation has on LLP forest health.

3.3.3 Disturbance Effects

Anthropogenic disturbance has lead to the reduction of habitats that are needed for natural species restoration and maintenance, as well as the degradation of training areas.

- Evaluate various ecosystem responses to human disturbances (short-term vs. long-term).
- Identify the varying degrees of disturbances affecting plant and animal species. The land type classification and management drivers for Camp Lejeune should be used to help prioritize ecosystems to be studied.
- Identify the best rehabilitation strategies for highly disturbed lands.
- Hurricanes affect the biological communities on Camp Lejeune and surrounding areas. Investigate if the forests can be managed to reduce the impacts of natural disturbances.
- Develop management tools to reduce the impacts of natural disturbances on forests.
- Anthropogenic disturbances need to be better quantified. Devise a sampling regime to collect more data on the frequency and intensity of training, incorporating GIS/remote sensing to assist in quantification.

3.3.4 Coastal Habitats

Camp Lejeune possesses several miles of coast bordering on Onslow Bay. This is a barrier island system that requires close monitoring and maintenance. It is also an area used by endangered sea turtles for nesting which, at times, directly interferes with military training.

- Identify the best management strategy for the barrier island system, including the steps necessary to maintain Onslow beach especially the military training area.
- Assess the physical and biological consequences of the techniques used.
- Determine the consequences of not managing the barrier island, in terms of both ecological and training impacts.
- Determine the effects of the different types of renourishment on predators in the surf zone in the fisheries habitat.
- Develop and evaluate alternatives to renourishing the beach, specifically for dune protection.
- Determine the consequences of not renourishing the beach, in terms of both ecological and training impacts.

3.3.5 Other Habitats and Species Issues

Besides LLP, there are many other species and landscapes that exist on and around Camp Lejeune. These must be taken into consideration when managing for healthy ecosystems. Understanding the connectivity between the various habitats and the environmental driving forces that support them is important when developing a BMP strategy. This issue was at the forefront of discussion and includes:

- Determine what functions Camp Lejeune's unique communities play in the greater region.
- Describe the connectivity of habitats affecting plant and animal species populations.
- Determine the affect on genetic variability in isolated species communities.
- Examine the restoration of habitats on a spatial scale that includes local, landscape, and regional perspectives.
- Quantify the benefit to specific identifiable species from connectivity (e.g., plants, animals, insects). Consider spatial scale.
- Identify regional strategies besides connectivity that would help improve species diversity and sustainability.
- Determine the genetic population structure and diversity needed for species sustainment.
- Describe the demography of at-risk species.

3.3.6 Other Land Management Issues

A number of other land management issues directly affect the maintenance of the terrestrial areas both for military training and support and for sustaining ecosystems or natural habitats.

- Document riparian buffer zone establishment and maintenance. Quantify the time required for riparian vegetation to recover after a disturbance.
- Better describe wetland restoration as a management tool.
- Determine the effect of watershed management strategies on water quality and fisheries habitat.
- Quantify urban storm drainage and how it affects water quality.
- Identify how to use wetland restoration as a management tool.
- Determine the biogeochemical effects of current and proposed management activities in various ecosystems. For example:
  - How is carbon sequestration influenced by changing a loblolly pine system to a LLP system?
  - How is management in pocosin influencing carbon and nutrient cycling?

3.4 CROSS-BREAKOUT RESEARCH ISSUES

It became clear during the Research Agenda discussions that there were several areas of overlap among the three breakout groups. Especially evident was a common belief that a holistic approach is required when considering the linkages between the atmospheric, terrestrial, and aquatic environments. Each group recognized the need to investigate the effects of land use and military training (e.g., burning, clear-cutting, buffers, ditching, channelization, salt marsh creation, live firing, amphibious traffic) on the ecosystem in terms of the duration, frequency,

and level of disturbance. All groups recognized the need to study contaminants (e.g., perchlorate, PAHs, heavy metals), their cycling, and toxicology. The demography and habitats of threatened, endangered, and at-risk species also were a shared concern.

4.0 MONITORING BREAKOUT GROUPS

As with the research breakout groups, the monitoring breakout groups were tasked to identify the ecosystem monitoring needs for the area in and around Camp Lejeune. The Coastal Systems breakout group focused on coastal regions from the littoral zone (out to about 10 meters depth in the ocean) up to the dunes; the Terrestrial Systems breakout group focused on regions of the installation and surrounding environs that may affect the ecosystem(s) of the immediate area; and the Estuarine Systems breakout group discussed issues relevant to the New River and its tributaries. The monitoring breakout groups were tasked to look at the issues on both a temporal and spatial scale.

The breakout groups used a number of the research items to focus their discussions (e.g., the monitoring of indicator species or geochemical processes). They also discussed the idea of coupling biological and physical-chemical indicators with remote sensing to facilitate ecosystem-level assessments of condition and change.

4.1 BACKGROUND

To provide a perspective of the extent of monitoring that is presently being undertaken at Fort Benning, Dr. David Price, U.S. Army Corps of Engineers (ERDC-EL) at Waterways Experiment Station, Vicksburg, Mississippi, presented information on the SEMP Ecosystem Characterization and Monitoring Initiative (ECMI). Under the ECMI, a team works with the host installation to gather, assess, and document historic and current ecological data sources and monitoring efforts. This team is also responsible for long-term ecological monitoring. Data from the characterization effort, the monitoring efforts, and the research teams all flow into a common data repository shared by all research teams and the installation managers.[9]

At Camp Lejeune, installation personnel have begun laying the groundwork for a comprehensive monitoring program, known as the Camp Lejeune Integrated Operations Network (CLION). Prior to initiating breakout group discussions to identify the components of a long-term monitoring plan, Mr. Daniel Egge, Camp Lejeune's Training Resources Management Division Technology Branch Chief, provided an overview of CLION explaining that the system is intended to function as a fully integrated and operational network of security, safety, meteorological, oceanographic, and acoustic/seismic sensors. Opportunities for the DCERP to leverage, and provide added value to, this new monitoring network were immediately apparent.[10]

Two of the three monitoring breakout groups, Estuarine and Coastal, raised and discussed a number of issues in addition to defining the data elements that should be monitored. These issues are presented below in separate sections of each breakout group's report.

---

[9] See SEMP ECMI Fact Sheet: http://www.cecer.army.mil/KD/SEMP/index.cfm?chn_id=1088.
[10] See Appendix 4 for a one-page description of CLION.

4.2 ESTUARINE SYSTEMS MONITORING

The discussions on estuarine monitoring centered on water quality and the processes that affect this quality within the estuary. The areas of focus were organized primarily on a temporal scale (i.e., continuous, short-term, long-term). The group raised several issues as being prominent or overriding – namely, the integrative nature of research and monitoring, as well as indicator identification and the importance of establishing reference conditions and stations. Some of Camp Lejeune's as yet undeveloped streams and tidal creeks could be used as reference sites against which other variables would be measured. Baseline data should be collected from these sites for comparative analysis purposes.

4.2.1 Data Elements to be Monitored

Parameters identified as being necessary to understanding the estuarine environment are listed below by category according to the recommended temporal scale. Further, several types and examples of instrumentation were noted.

4.2.1.1 Continuous (Real-Time)

- **Aquatic Physical**: water level (benchmarked), light attenuation, conductivity, turbidity, temperature, salinity, groundwater level, currents (Acoustic Doppler Current Profiler).
- **Atmospheric Physical**: rainfall, through-fall, composition of atmospheric deposition (dry/wet), wind (intensity/direction), vertical and horizontal fluctuations in carbon dioxide, and nitrogen oxide (eddy correlation towers).
- **Aquatic Chemical**: Dissolved oxygen (DO), pH, Eh, nutrients (ammonium, nitrate, phosphate).
- **Biological**: chlorophyll *a* (by fluorescence or absorbance), metabolism (DO), fish activity and presence (scanning acoustic monitoring/autonomous underwater vehicles [AUV] video monitoring), biomonitoring.

4.2.1.2 Short-Term (Episodic, Daily, Weekly, Monthly, Seasonal)

- **Water Column**
  - Nutrients (dissolved and particulate organic, inorganic)
  - Biological oxygen demand
  - Water color, dissolved organic matter (lability, composition)
  - Chlorophyll *a* and other diagnostic photopigments
  - Phytoplankton/zooplankton community composition
  - Primary production (Photosynthesis/irradiance curves) and microbial secondary production
  - Pathogens (source tracking), parasites
  - Microbial community characterization by molecular techniques (pathogens, harmful algal blooms)
  - Biogeochemical measures – nitrogen cycling (nitrification, nitrogen fixation, denitrification, mineralization)

- **Sediment Characterization**
  - Grain size, porosity, bulk density
  - Nutrient and organic content (pore water)
  - Chlorophyll and other photopigments
  - Contaminants – organics, metals (1 major survey then intermittent)
  - Primary production/respiration and microbial secondary production
  - Benthic community composition (microalgae, meiofauna, macrofauna)
  - Pathogens (molecular techniques)
  - Benthic Index of Biotic Integrity (annual)
  - Biogeochemical measures – nitrogen cycling (nitrification, nitrogen fixation, denitrification, mineralization)
- **Groundwater/Baseflow**
  - Discharge rate (direct discharge into river vs. baseflow into creeks)
  - Nutrient loads
  - Contaminants
- **Higher Trophic Levels**
  - Fish, crustaceans, mollusks, birds, insects, manatees, turtles, alligators, beavers, etc. (make use of historic databases)
- **Marshes**
  - SET tables
  - Pore water samplers (piezometers, wells, diffusion)
  - Elemental composition
  - Sediment characterization (1 major survey then episodic)
  - Primary production/respiration
  - Exchanges with tributary
- **Bathymetry (1 major survey then episodic)**

4.2.1.3 Long-Term (decadal +)

- **Core Profiles:** accretion, organic content, microbial biomarkers, heavy metals and use of paleoecology
- **Landscape Metrics:** land use, fragmentation, elevational changes

4.2.1.4 Instrumentation / Data Gathering

- **Moorings/Data Sondes/Observing System (seek partnerships)**
  - Flow cam
  - YSI™ hydrolab
  - Continuous nutrient sensors
  - Pulse amplitude modulated (PAM) fluorescence
  - Electrochemical microbial monitor
- **In Situ Sensors**
- **Remote Sensing**
  - AUV for fish, DO, salinity, temperature
  - Satellite imagery for phytoplankton and higher plant communities
  - Aerial sensors for submerged aquatic vegetation, salt marshes, ocean color

    - IR source identification for sewer pipes, groundwater discharge
    - LIDAR for landscape profiles
- **DataFlow (2 dimensional spatial variability); Acrobat (3 dimensional spatial variability)**

4.2.2 Other Monitoring Issues

The following three areas constitute additional monitoring discussions principally focused on estuarine areas but also relevant to the coastal and terrestrial areas.

4.2.2.1 Modeling Needs

Models are a valuable tool for analyzing data collected as part of the monitoring plan. Their utility is maximized when historic datasets are synthesized and incorporated. However, models must be developed and/or applied at environmentally relevant scales. Examples follow:

- Hydrodynamic
- Water Quality (biogeochemical/mass balance)
- Hydrology/Watershed/Landscape
- Hypsometry
- Ecosystem (population)

4.2.2.2 Spatial Scale Considerations

In addition to recommending the frequency of monitoring specific parameters, there is a need to consider the spatial scale when locating monitoring stations. Reference stations are one component to consider; however, more importantly, there is a need to establish fixed positions. When locating monitoring stations:

- Identify and consider historical monitoring locations.
- Consider physical-chemical-biotic interactions and their relevant scales.
- Give special attention to the intertidal, littoral zone, and channel areas.
- Create depth profiles for within the water column.
- Consider the regional perspective.

4.2.2.3 Problems Related To Monitoring

To increase awareness and foresight in development of the monitoring plan, the group raised several issues that commonly hinder monitoring efforts. As mentioned previously, positioning monitoring stations requires consideration of fixed, dynamic, and random locations; synoptic sampling; and vulnerability of the locations to adverse human activity. There are also logistical issues of adequate access to the monitoring stations given training activities. Security clearances may be required. Sensors often must be maintained to avoid fouling. Instrumentation must be calibrated and quality assurance/quality control procedures established to maintain specified data collection standards. Once collected, data must be handled appropriately for later synthesis, modeling, and analysis. Most importantly, there is a need to couple and integrate the monitoring efforts planned for DCERP with the ongoing initiative at Camp Lejeune to establish the CLION.

4.3 COASTAL SYSTEMS MONITORING

In the Coastal monitoring breakout group, the primary emphasis was the monitoring of the ocean from approximately 10 meters depth to the shore, and the adjacent beaches and dunes. Other discussions arose that emphasized or supported various monitoring needs. Related to these biotic and abiotic monitoring efforts is the documentation of military training efforts on both spatial and temporal scales in the coastal zone.

4.3.1 Data Elements to be Monitored

A need for both baseline data and data yielding comparisons over time, particularly after major storms, hurricanes, beach renourishment, or major base use of beach by vehicular traffic was established. The sensors noted with an asterisk (*) are real-time monitoring requirements. Information collection other than through on-site sensors is also required especially for detailed analyses of areas and variables, including nutrients in the benthos and sediments.

4.3.1.1 Sub-surface and Surface Sensors[11]

- Currents profiles*
- Temperate profiles*
- Salinity profiles*
- Wave fields (direction, height, frequency)*
- Wave and swell parameters
- Water-level gauges
- Surface-air temperatures*
- Wind speed and direction*
- Rainfall
- Air visibility*
- Turbidity*
- Optical properties of the water
- Toxins, nutrients, and contaminants – sensor development is evolving and should be incorporated when ready. Meanwhile, these variables can be monitored. [Note: sensors are currently being developed for molecular-based reporting (pathogens, harmful algal blooms/HABs, etc.)]
- Chlorophyll *a* and other diagnostic photopigments
- Acoustic climate (hydrophone-mounted buoys)

[11] Routine monitoring of nutrient transformations (e.g. nitrification, denitrification, N2 fixation, CO2 fixation) should accompany sensor-based measurements.

4.3.1.2 Beach/Sand Dune Zone (summary)

- Beach and dune profiles and shoreline stability (2-4 times/year)
- Natural sand deposition/loss rates
- Vegetative structure (minimum: seasonally)
- Dune topography
- Grain size and biological habitat (monitor at least seasonally/quarterly)
    - prey community/structure
    - colonial shorebird (also piping plover)
    - ghost crabs
    - sea turtle false crawls/nest achievement
    - amaranth

4.3.2 Issues to Consider in Coastal Monitoring

The following sections constitute additional discussion on the rationale and means by which the parameters listed above should be monitored in coastal regions.

4.3.2.1 Temporal Considerations

One identified need was for regular or seasonal monitoring transects to more effectively document changes to current and future conditions. Three areas of research relevant to temporal monitoring include:

- Immediate offshore benthic habitat.
- Properties of the beach, physical and geological (the available beach habitat, where are the dunes going, are they flattening out, slope/horizontal extent/sand/beach profiles, etc.).
- Productivity and characterization of near-shore waters (this should be set up to examine the effects and impacts of episodic events vs. chronic trends).

4.3.2.2 Benthic Habitat

The benthic habitat considered here is that immediately offshore.

- Offshore live rock/coral are extremely important for fish nursery activity. This activity needs to be examined in terms of productivity and food web dynamics.
- Benthic habitat is extensive and unique, including both sand bottom and hard bottom outcrops that support coral and provide structure and refuge for fish communities.
- Almost all the bottom is illuminated and capable of food production—significant because anything that CAN grow will grow, if allowed.
- Benthic plant communities may be highly useful indicators of eutrophication.
- Plumes are granular and short in duration so will not completely limit light to system. The plumes are pulses of nutrients and sediments, and can generally be tracked by following the fishing boats.
- Importance of benthic structure: There is currently a lack of near-shore monitoring, especially in embayments. This should be a fairly routine monitoring activity.

- Need to ask first how dynamic the system is, since this will determine rate of monitoring. The idea is to monitor seasonal patterns and change over time, but how "time" is measured must be defined.
- Before any monitoring system is deployed, personnel must have a very good map of benthic habitat (e.g., because bottoms vary). First step must be to develop a distribution map.
  - A set of physical benchmarks of the beach is needed in order to geo-rectify all the monitoring efforts for the very long-term efforts.
  - Seasonal monitoring will continue to be needed.

4.3.2.3 Geological/Physical Processes

The physical/geological properties, including those of the beach, are the most important in the viewpoint of various stakeholders. Several questions and issues were raised.

- What is the available beach habitat?
- Where are the dunes going?
- Are the dunes flattening out? Need to gauge slope/horizontal extent/sand/beach profiles.
- How much sand is migrating away, and at what rate?
- What is the impact of troop use of beach?
- What is the quality of habitat immediately offshore from beach?
- How much sand is there to work with?
- Position and maintenance of the waterways will affect what is done (e.g., if have big ditch behind dunes, that affects quality/productivity).
- A balance between productivity and restoration in the system needs to be established. Tracer processes (C^{14} among others) may be used for this.
- Issues of productivity are significant for coastal waterways. For the ocean, it is the condition of beach and live rock outcroppings that is significant. The order of approach is not clear.

4.3.2.4 Productivity

Productivity and characterization of near-shore waters is a major monitoring effort. It was recognized that the effects of episodic events versus chronic trends need to be distinguished. Issues and questions were again raised in an effort to direct the monitoring needs for productivity.

- What is the productivity of the system?
- What are the seasonal profiles? Hyperspectral imaging could be used to obtain temporal information as to primary productivity and mass.
- How fast is that changing and is the change beneficial or not?
- What are the rates of carbon fixation/accumulation, benthic production/restoration?
- Need to undertake seasonal productivity studies that would use a transect that extends from the mouth of the river and capture the outflow of the river system and beyond.
- There would have to be some additional reference sites at locations where larger scale features are being studied. Those productivity sites should be coupled to physical, chemical,

biological parameters that should be collected simultaneously (e.g., light, nutrients, stratification, structure of water column).

- Coastal ocean productivity: Fishing is a huge resource within the live rock/coral (e.g., New River inlet). Is this a TES or productivity issue? Are they being impacted now or not? These are the biological integrators that can be examined as **indicators** of productivity.
- Need to establish a long-term database so can develop data for overall system productivity. This includes examining the installation's activities and investigating their impacts.
- Monitoring broad-scale changes over time is needed because there are no systems currently in existence for doing this.
- Local vs. regional impacts: Important to establish a long-term data base to separate local from regional effects/impacts on productivity and respiration of the system.
- Land to sea continuum and various impacts of land use activities on the system from small tributaries to the ocean.
- HABs, fisheries, etc. need to capture long-term and broad changes.
- There should be periodic monitoring to determine the system's productivity (e.g., nutrients, chlorophyll, circulation, mixing, optical properties of water). There is a need to couple collection of samples to productivity indicators/metrics.

4.3.2.5 Nutrient Cycling

Trophic systems change over time and require qualification and quantification with respect to varying climatic events, seasons, other activities, nutrient inputs, etc. These need to be measured over long time periods. There is a need to link nutrient inputs to productivity, and determine how changes in microbial and higher tropic levels will impact nutrient cycling and availability of nutrients. There must be long-term documentation of eutrophication.

4.3.2.6 Modeling

Extensive use of modeling was identified as a significant component of the overall monitoring effort. Specifically, changes in community structure and those related to water quality and benthic processes need to be modeled to ensure that changes in sea level rise over time (an issue relevant to all aspects of coastal monitoring) are captured.

4.3.2.7 General Monitoring Issues

Determining the spatial array of existing buoys within the New River estuary was identified as a need, as was a physical delineation of a usable transect system for any additional monitoring stations before embarking on a serious data collection effort. Also, given that deployment of moorings is known, scientists must determine if they are usable and can serve as good reference sites within a larger monitoring network.

4.4 TERRESTRIAL SYSTEMS MONITORING

The terrestrial systems monitoring breakout group addressed many of the items discussed above, but focused their efforts on dry land issues. The information they discussed grew out of the

terrestrial research breakout group's discussions, and focused on environmental drivers and the need to identify indicators to monitor for change.

4.4.1 External Drivers of Change

External drivers of change refer to those activities that occur outside or independent of the system but that have direct or indirect effects on the system. Some of these events occur under conditions over which resource managers have little or no control.

- Wildfire
- Changes in training type and intensity
- Changes in equipment
- Human population/anthropogenic impacts
- Climatic events (e.g., rainfall, hurricanes)
- Climate change
- Changes in management
- Changes in regulation
- Changes in infrastructure
- Rise in sea level

4.4.2 Landscape Indicators

Landscape indicators refer to those occurrences within a system at a higher spatial scale than at an individual or community level. Many of these can be determined and monitored over time by remote sensing at various levels including intermittent aerial surveys and regular satellite imagery.

- Degree of fragmentation
- Land use allocation including extent of community
- Measures of connectivity among RCW clusters
- Productivity
- Extent and productivity of pocosin
- Index of biotic integrity
- Measure of total diversity
- Discharge from wetland areas
- Hydrologic measures (water table [4 times/day], surface runoff, discharge)
- Change in nutrient capital
- Measure of loblolly senescence
- Tree mortality
- Extent and effectiveness of prescribed burns
- Extent and effect of wildfire
- Number of acres with training restrictions

4.4.3 Community Indicators

Community indicators refer to those occurrences within a system at a higher spatial scale than at an individual level but occur lower than the landscape level.

- Bird species/composition
- Amphibians and reptiles
- Invertebrates (e.g., ants)
- Plant communities (diversity/composition)
- Quality of habitat (e.g., health)
- Depth and composition of the forest floor duff layer
- Soil microbiology, compaction, and organic matter
- Cover or basal area of bunch grass
- Carbon
- Nitrogen
- Sand/beach (e.g., volume, quantity)
- Height/density of mid-story
- Size/class distribution of dominant pine
- Number of acres that meet foraging guidelines
- Correlation between prescribed burns and training usage
- Distribution and effectiveness of fire and training
- Growth of RCW population

4.4.4 Issues of Concern for Individual Species

Events occur at a lower spatial scale than the community level and can impact the individual species level.

- Species presence/absence
- Species abundance
- Species diversity
- Demographics
- Pest species (native and exotic)
- Game species populations

4.5 CROSS-SYSTEM MONITORING ISSUES

The Coastal, Estuarine, and Terrestrial monitoring breakout groups identified a number of common themes. For example, all of the groups noted key aspects to consider when installing and using any monitoring system (e.g., CLION). Participants noted that monitoring efforts should be coordinated closely with existing research and management initiatives (e.g., ongoing SERDP/SEMP activities), especially when identifying relevant indicators at the landscape, community, and individual levels. They also pointed out the need for both baseline data and data yielding comparisons over time, particularly after major storms, hurricanes, beach restoration

and disturbance activities, and changes in management or regulations. All groups identified specific data elements to be monitored, and recommended monitoring frequencies for many.

Other discussion commonalities included that spatial scale considerations are paramount in establishing and using fixed station positions to assess local and regional impacts, that a long-term database is needed to assess episodic impacts and effects of climate change (to allow ongoing documentation of changes), and that synthesis of historic data sets and modeling should be part of the overall effort.

5.0 CONCLUSIONS

Maintaining military ranges is crucial to accomplishing DoD's mission of providing realistic training in a sustainable manner. Similarly, successful ecosystem management is critical for minimizing military training impacts, and is the cornerstone of the military's efforts to protect the wealth of natural resources found on installations. SERDP, DoD's primary environmental R&D program, has launched the DCERP at Camp Lejeune, North Carolina, to investigate estuarine issues of interest, and to monitor the impacts of DoD operations in various aquatic environments. To better direct DCERP efforts, a formative workshop was held to seek the knowledge of experts in the field to determine the state of science and identify current gaps in research and monitoring. The task given to workshop participants was to develop and articulate research questions and monitoring needs pertinent to the effective management of the New River watershed and long-term sustainability of Camp Lejeune ecosystems. The results were a series of questions, suggested directions, and recommendations that will be used to establish a scientific direction for DCERP in the coming years. The first four components of this section integrate conclusions provided by the three research breakout groups. The monitoring breakout group conclusions follow these.

5.1 CHARACTERIZATION

The reason for implementing a characterization process is to provide a baseline understanding of the conditions that exist so that appropriate short- and long-term research objectives can be developed, and that progress can be tracked over time to measure overall initiative progress and success of the initiative.

Recognition that environments are dynamic and responsive to synergistic physical, chemical, and biotic stressors is essential. Similarly, it is important to understand present-day conditions in terms of ecosystem structure and function, and to gather both baseline data and data yielding comparisons over time. Models should be developed and/or applied at environmentally relevant scales, and all data should be comprehensive and should synthesize historic data sets, as appropriate. Two areas of particular interest include hydrodynamics and community structure.

Hydrodynamics: The hydrodynamic properties of the New River watershed are largely unknown. Researchers should establish baseline data on nutrient, sediment, and contaminant flow; determine their sources and how training impacts their levels; and assess where and how water quality might best be improved. Additionally, the determination and monitoring of the quantity, quality and flow of on-installation groundwater is of paramount concern to installation

personnel as they plan future troop activity at Camp Lejeune. Researchers need to measure direct discharge of groundwater into the river, and determine the impacts of external inputs (surface, subsurface, atmospheric) and stressors to internal biogeochemical cycling and sediment/water column interactions.

Community Structure: It is important to develop and apply indices of biodiversity and abundance to measuring changes within biological communities. Specifically, researchers should examine the functions of animals and plants in both aquatic and terrestrial habitat types. With respect to aquatic communities, there is a need to develop biological monitoring tools, as well as in situ and remote sensors, to accurately determine the impacts from changes in the input and cycling of constituents, wave action, troop maneuvers, weapons systems, and amphibious assault vehicles.

5.2 DISTURBANCE

Much is yet unknown about the impacts of land use (e.g., burning, clear-cutting, buffers, ditching, channelization, and salt marsh creation), and training practices (e.g., live firing and amphibious traffic) on the transport and biotic fate of nutrient and other inputs transport and biotic fate. There is a need to investigate these impacts, as well as those from erosion and sea level rise as they relate to various activities and management regimes (e.g., how the range of ecosystems respond to human and natural disturbances, and how various degrees of disturbance affect plant and animal species). Relevant to RCW management, areas of research interest include impacts to the biological community with respect to land use, fragmentation, and elevation changes, focusing especially on consequences to the demography of threatened, endangered, and at-risk species.

Fire: Due to periodic wildfires and the installation's aggressive prescribed burn program, fire plays a significant role in Camp Lejeune's ecosystems. Examination of both episodic and chronic nutrient, sediment, contaminant, and pathogen inputs to various systems from prescribed burns and wildfires is important.

Training: Research and monitoring activities must be conducted with an understanding that training impacts (including the recognition that impacts are episodic and vary in intensity) water quality, sedimentation, and TES habitats. Additionally, impacts must be understood within the context of other disturbances (natural versus anthropogenic). Consequently, improved troop tracking methods and nutrient/sediment indices at the watershed and sub-watershed levels should be established before data quantification and analysis begins. Once preliminary research determines what (if any) significant impacts may be occurring, a long-term monitoring system can be established.

Contamination and its Sources: Eutrophication within the New River and its tributaries is a significant issue for Camp Lejeune and the surrounding communities. Impacts of episodic versus chronic nutrient, sediment, contaminant, and pathogen inputs (varying frequencies of disturbance, stormwater dynamics, role of impermeable surfaces and buffers) should be examined as possible causes for eutrophication. Beyond that, there is a need to identify source(s) of pollution and contamination in waters adjacent to and on Camp Lejeune. The underlying

hypothesis behind this watershed source assessment is that the greatest pollution-reduction benefits will come from upstream monitoring and management.

5.3 RESTORATION

Natural and anthropogenic forces impact ecosystems to varying degrees. When impacts are severe, restoration of natural systems and their functions may be required. The goal for all restoration efforts should be net habitat and water quality gains. While largely an engineering undertaking, restoration must be examined in an ecosystem context at varying spatial scales, and should be targeted towards restoration and eventual sustainment of both the longleaf pine and coastal systems, including the dunes and barrier island. Restoration opportunities may also exist for streams, tributaries, and inter-tidal areas.

Longleaf Pine: Longleaf pine (LLP) habitat restoration should focus on both temporal and spatial factors, including impacts to other systems and species within the system. Additionally, research is needed to determine the most effective way to restore LLP in a senescing loblolly dominated landscape while expanding RCW populations, and maintaining or expanding land use for mission sustainability.

Coastal Beaches and Dunes: Because the coastal system fills critical roles for the installation in terms of both training and ecosystem function, it represents a significant area for future research and monitoring efforts. Prior to initiation of restoration efforts, physical disturbance processes (storms/wind, erosion, nourishment, vehicular traffic) must be investigated within the context of natural sediment dynamics. Furthermore, since even less is known about the status and dynamics of either the dune or barrier island ecosystems, before a management regime is initiated in these areas, research must determine how best to manage the systems and what the short- and long-term consequences of inadequate management would be. Once these are known, best management practices can be developed and appropriate monitoring systems implemented.

5.4 INDICATORS AND THRESHOLDS

Indicators and thresholds are rapidly developing as tools for monitoring and managing ecosystem disturbance and stress, especially when coupled with remote sensing technologies. Researchers must identify appropriate ecological indicators of physical and/or chemical change and ecological stress, and establish thresholds for physical, chemical, and biotic drivers of change.

5.5 MONITORING

Monitoring of the various ecosystems – coastal, estuarine, and terrestrial – to note and record the changes of in these the systems and their components with respect to natural and anthropogenic influences is an important aspect of the proposed research. Workshop participants provided extensive lists of the monitoring needs for each system so that the research needs are correctly met. They also addressed some of the regulatory issues that are now, and may later be, imposed on the installation. The reasoning for some of the specific monitoring needs, and the listed parameters and suggested instrumentation and/or methods are provided above in Section IV – Monitoring Breakout Groups. Participants specifically indicated that the first step in the process

should be to assess trends and ecological change over different temporal and spatial scales in a way that distinguishes between natural and anthropogenic changes, as well as between episodic events and chronic trends.

6.0 RECOMMENDATIONS

In order to better integrate research and monitoring efforts conducted on the installation and regional initiatives in the New River and surrounding watershed, workshop participants highlighted several overarching recommendations to guide the scientific direction of the Center over the next five years. Interestingly, many of the recommendations mirror themes that emerged from SERDP's Ecosystem Management Workshop held in 1997. Others reflect the unique focus of the DCERP workshop on coastal and estuarine issues.

6.1 EMPHASIZE COASTAL AREAS

The beach, dune system, and barrier island on and adjacent to Camp Lejeune provide significant and essential training opportunities for DoD. Because there are many unknowns regarding these coastal areas, determining current and potential future training impacts to them is warranted. Similarly, in order to appropriately maintain these systems, it is important to identify best management practices (BMPs) for assessing the physical and biological consequences of various anthropogenic and natural activities (see Sections 3.1.5, 3.3.3, and 3.3.4; summarized in 5.3).

- *Rationale*: Better understanding of the coastal/beach, dune, and barrier island systems at Camp Lejeune.
- *Components*:
    - Identify and evaluate the physical disturbances that impact these ecosystems, especially those that disturb physical structures and indigenous biota.
    - Conduct research on the effects of renourishment, alternatives to renourishment, and the consequences of not re-nourishing the beach.
- *End Product*: Management plan for Camp Lejeune's coastline.

6.2 INVESTIGATE SPATIAL AND TEMPORAL SCALES

There is a need to better understand the impacts of varying spatial and temporal scales of disturbance (anthropogenic and natural) on ecosystem structure and function. A precursor to this level of understanding is a holistic assessment of the ecosystem (see Section 3.1 and 7.2; summarized in Section 5.1).

- *Rationale*: To improve the management of natural resources at Camp Lejeune in relation to the ongoing military mission
- *Components*:
    - Historic information (e.g., paleodisciplines, long-term data sets) to identify ecological changes and trends in habitat quality over varying temporal scales.
    - Current evaluations at specified intervals and locations to determine the abiotic and biotic interactions and feedback loops within the ecosystem.
    - Spatial scales ranging from the New River estuary to the entire region.

- *End Product*: Baseline data for assessing the impacts of disturbance throughout the entire New River/Camp Lejeune region.

6.3 DEVELOP INDICATORS AND THRESHOLDS

Indicators and thresholds represent management tools for monitoring trends in community structure and function (i.e., ecosystem health), and for determining an ecosystem's carrying capacity at varying levels of disturbance and stress (see Sections 3.1, 3.1.2, 3.1.3, 3.2, 3.2.4, and subsections within 4.4; summarized in Section 5.4).

- *Rationale*: To develop a set of indicators and thresholds that can be incorporated into the monitoring plan.
- *Components*:
    - Physical, chemical, and biotic drivers of change (e.g., burning, runoff, resuspension) that may have direct or indirect effects on the system.
    - Spatial scales ranging from landscape to community to the organism.
    - Investigate integrative environmental indicators (e.g., shellfish, SAV).
- *End Product*: A warning system for potentially significant changes in the ecosystem.

6.4 ADDRESS WATER QUALITY ISSUES

One of the driving forces in water quality is the introduction of natural and manmade inputs that exceed normal levels. Because the hydrodynamic properties of the New River watershed are largely unknown, there is a need to develop biological monitoring tools, as well as in situ and remote sensors to accurately determine the impacts from changes in the input and cycling of constituents, wave action, and military training activities; upstream (i.e., off-installation) inputs, especially non-point sources; and, the role of various natural processes, including significant climatic events (e.g., hurricanes). Identifying these sources, measuring their inputs, and determining their impacts is crucial to understanding the system (see Sections 3.1, 3.1,1, 3,1,6, and subsections within 3.2; summarized within 5.1).

- *Rationale* Identify and assess sources of actual and potential contamination from throughout the New River watershed.
- *Components*:
    - Develop and/or apply models that have predictive value, offer application of quantification methods, and/or that consider the importance of various system interactions (e.g., upstream inputs, storm water runoff, influence of light).
    - Develop water quality metrics for both the New River and estuary.
    - Expand CLION monitoring capabilities.
    - Identify pathogen (BST/MST) indicators, and determine their fate across the land/water interface.
    - Ensure comprehensiveness of data through synthesis of historic data sets.
- *End Product*: Improved water quality through targeted and measurable source control.

6.5 BETTER UNDERSTAND IMPACTS OF RCW MANAGEMENT

Significant resources have been, and continue to be, devoted to RCW management at Camp Lejeune. As such, longleaf and loblolly pine forests that dominate the installation's upland areas are currently being managed for recovery of the RCW. Yet, current management practices are often implemented without the full understanding of their impacts to other species and systems (see Sections 3.3, 3.3.1, and 3.3.2).

- *Rationale*: Improved understanding of tertiary impacts from RCW management.
- *Components*:
    - Impacts to soil, vegetation and other species of management concern from commonly used management protocols (prescribed burns, clearing, erosion).
    - Reaching RCW recovery goal and quality habitat goal while maintaining a sustainable mission.
    - Understanding the consequences or implications to the total biological community of managing for the RCW in LLP habitat.
- *End Product*: Continued RCW recovery with minimized negative impacts to non-LLP habitats and species; enhancing general species and habitat diversity.

7.0 GENERAL GUIDELINES

Workshop participants felt strongly that the proceedings should reflect some general guidance for the Center Director(ate) and others who will later be tasked with implementing the DCERP. The following sections reflect this guidance and advice.

7.1 EDUCATION AND OUTREACH

Education and outreach should be integrated within all research projects and within the overall monitoring effort. Targets for education and outreach should include graduate students, Camp Lejeune resource managers, and the public. For certain issues (e.g., non-point source pollution), it is especially important to establish open communication and foster cooperative efforts among stakeholders. It is equally important that researchers be in tune to the priorities of the community and base personnel.

7.2 SYNTHESIS OF HISTORIC INFORMATION

Significant quantities of information and data from previous research projects and monitoring efforts exist for the New River watershed. Synthesizing this information is a critical component of establishing a baseline from which the impacts of changes in levels and frequencies of ecosystem disturbance and stress can be assessed. Further, historic information will help in locating monitoring stations and analyzing the impacts of natural versus anthropogenic events. Paleo-disciplines, techniques, and research should be used to determine prehistoric conditions, and historic data mining of national, state, and local data sets (e.g., water quality, fisheries records, and natural resources) should be used to identify ecological change and trends in habitat over different scales.

7.3 COORDINATION AMONG RESEARCHERS

A top priority for the Center Director(ate) should be coordinating efforts among researchers and within the monitoring program, as well as drawing meaningful conclusions from the breadth of data available at the installation and from the surrounding region. This will require development of a monitoring program that augments research efforts, incorporates standard metrics and reporting standards, and utilizes a powerful and readily accessible database. Coordination meetings should be held at periodic intervals to facilitate information and data transfer. For non-meeting times, a well-maintained website accessible to researchers, the installation, advisory boards, and outside groups should provide up-to-date information and serve as a major communications link. It is especially important to coordinate efforts with respect to issues of encroachment and water quality, and to examine preventive maintenance efforts for all utility areas. For example, by examining non-point sources, a determination of whether mitigation efforts are effective can be made.[12]

7.4 EFFORTS SUPPORT PROACTIVE MANAGEMENT

DCERP-related research and monitoring efforts should support proactive management of the New River watershed, thereby helping ensure that activities do not have negative impacts on key habitats and species, water quality, or training lands. Research (i.e., Statement of Need development) and monitoring (e.g., positioning stations) should anticipate future needs and requirements.

For the DCERP, researchers must establish an a priori set of questions. Metrics will serve as measures of success for changes in management strategies of nutrient, sediment, and toxicant inputs to the ecosystem, as well as TES and other species recovery. When developing metrics, appropriate temporal and spatial scales over which to measure change must be determined in advance. Researchers must ensure uniformity in source sampling and other techniques and, if different groups are collecting information and data, each must know who will be responsible for completing the comprehensive assessment, including data management and access opportunities. The Director(ate) must also ensure data comprehensiveness, because these data will provide the basis for the development of future questions and work requirements.

7.5 MONITORING ACTIVITIES COORDINATED WITH RESEARCH

The monitoring plan should be developed in coordination with the formulation of an initial research plan. In this way, the ability of research and monitoring efforts to augment one another throughout their duration will be enhanced. The monitoring plan should encompass the watershed, and have the flexibility to adapt as new research directions and priorities are established.

A randomized statistical confidence approach should be used so that monitoring efforts can be repeated over time (several years) to express results with known confidence. Where possible, standardization of methodologies used by researchers should be incorporated. The ICW and adjacent waters should be included in monitoring activities (e.g., shoreline sloughing, modeling

[12] Suggest using RCW activities as an example/model.

of likelihood for storm overwash). The monitoring plan should take advantage of scientific improvements in remote sensing (e.g., use flyovers for mapping and real-time ground truthing).

Appendix 1: Workshop Agenda

DEEMRC PLANNING WORKSHOP

10-12 February 2004

Sheraton Atlantic Beach Oceanfront Hotel
2717 West Fort Macon Road
Atlantic Beach, NC 28512
Phone: (252) 240-1155; Fax: (252) 240-1452
www.sheratonatlanticbeach.com

Purpose: Develop the broad design for a monitoring plan and identify research needs to provide scientifically-based tools for installation managers (and community leaders) to sustainably manage estuarine ecosystems while undertaking the installation's mission.

Tuesday, February 10, 2004

0730-0830 Continental Breakfast

0800-0805 Welcome – Mr. Bradley Smith, SERDP Executive Director

0805-0815 Introduction to Camp Lejeune – Commanding General

0815-0900 Workshop Purpose and Scope – Mr. Smith

0900-1000 Overview of the Camp Lejeune/New River Watershed –
Lt. Col. Gary Oles, Mr. John Townson, and Mr. Scott Brewer, Camp Lejeune

1000-1015 Break

1015-1100 Related SERDP Work – Dr. Robert Holst, SERDP

1100-1145 SERDP Ecosystem Management Project (SEMP) -
Mr. William Goran, U.S. Army Corps of Engineers (COE) ERDC-CERL

Overview of Fort Benning's Perspective - Mr. Pete Swiderek, Fort Benning
Overview of Data Repository - Dr. David Price, U.S. Army COE ERDC-EL

1145-1200 Introduction to Breakouts – Mr. Smith

1200- 1300 Lunch (en route to Camp Lejeune)
1300- 1700 Tour of Camp Lejeune and New River

1700-1900 Free Time and Dinner

1900-2000 Research Agenda Breakout Groups Begin Discussions

Wednesday, February 11, 2004

0730-0800 Continental Breakfast

0800- 0845 Related Work at Camp Lejeune
Camp Lejeune Integrated Operations Network (CLION) –
Mr. Daniel Egge, Camp Lejeune

0845-1145 Research Agenda Breakout Groups Continue
Water Quality
Terrestrial Habitat
Aquatic Habitat

1000-1015 Break

1145-1315 Lunch (buffet at hotel)
Presentation – History of Camp Lejeune and 2nd Marine Division –
Mr. Chuck Van Horne, Camp Lejeune

1315-1415 Research Agenda Breakout Groups Continue

1415-1430 Break

1430-1530 Research Agenda Breakout Groups Report Out

1530-1545 Introduction to Monitoring Breakout Groups
Terrestrial
Estuarine
Coastal

1545-1800 Monitoring Breakout Groups Begin Discussions

1800 Dinner

Thursday, February 12, 2004

0730-0800 Continental Breakfast

0800-0900 Presentation - Synthesis of Research Breakout Group Results into Overarching Questions

0900-1030 Monitoring Breakout Groups Continue

1030-1045 Break

1045-1130 Monitoring Breakout Groups Report Out

1130-1200 Wrap Up - General Discussion on Research Plans and Monitoring –
Mr. Bradley Smith and Dr. Robert Holst, SERDP

1200 Meeting Adjourn

Appendix 2: Workshop Participants

Dr. Iris Anderson
College of William and Mary
School of Marine Science
Virginia Institute of Marine Science

Mr. Fred Annand
The Nature Conservancy,
North Carolina Chapter

Mr. Brynn Ashton
Marine Corps Base Camp Lejeune

Dr. Mary Barber
Environmental Consultant
SERDP Scientific Advisory Board

Mr. Scott Brewer
Marine Corps Base Camp Lejeune

Dr. Mark Brinson
East Carolina University
Biology Department

Dr. Carolyn Currin
NOAA National Ocean Service
Center for Coastal Fisheries and
Habitat Research

Ms. Alison Dalsimer
HydroGeoLogic, Inc.
SERDP Support

Brigadier General Robert Dickerson
Marine Corps Base Camp Lejeune

Mr. Duncan Dawkins
Marine Corps Base Camp Lejeune

Mr. Daniel Egge
Marine Corps Base Camp Lejeune

Dr. Jack W. Fell
University of Miami
Rosenstiel School of Marine and Atmospheric
Science (RSMAS)

Dr. J. Wendell Gilliam
North Carolina State University
Soil Science Department

Dr. Howard Glasgow
North Carolina State University
Center for Applied Aquatic Ecology

Mr. William Goran
U.S. Army Engineer Research and Development
Center (ERDC)
Construction Engineering Research Laboratory
(CERL)

Dr. Nick Haddad
North Carolina State University
Department of Zoology

Dr. Robert Holst
SERDP/ESTCP Program Office

Mr. Dennis Ihnat
University of North Carolina at Wilmington
Center for Marine Science

Ms. Leslie Karr
Naval Facilities Engineering Service Center

Dr. Ronald Kneib
University of Georgia
Marine Institute

Mr. Martin Korenek
Marine Corps Base Camp Lejeune

Mr. Carmen Lombardo
Marine Corps Base Camp Lejeune

Dr. Rick Luettich
University of North Carolina
at Chapel Hill
Institute of Marine Sciences

Mr. Todd Miller
North Carolina Coastal Federation

Dr. Michael Mallin
University of North Carolina
at Wilmington
Center for Marine Science

Mr. Daniel Marshburn
Marine Corps Base Camp Lejeune

Dr. James Morris
National Science Foundation
Division of Environmental Biology

Dr. Marvin Moss
University of North Carolina
at Wilmington
Center for Marine Science

Lieutenant Colonel Gary Oles
Marine Corps Base Camp Lejeune

Dr. Hans Paerl
University of North Carolina
at Chapel Hill
Institute of Marine Sciences

Dr. Charles Peterson
University of North Carolina
at Chapel Hill
Institute of Marine Sciences

Dr. Michael Piehler
University of North Carolina
at Chapel Hill
Institute of Marine Sciences

Mr. Scott Pohlman
North Carolina Natural Heritage Program
Office of Conservation and Community Affairs,
Department of Environment
and Natural Resources

Dr. Freda Porter
Porter Scientific, Inc.

Dr. David Price
U.S. Army Engineer Research and Development
Center (ERDC)
Environmental Laboratory

Mr. Jay Sauber
North Carolina Division of Water Quality

Ms. Julie Shambaugh
Marine Corps Base Camp Lejeune

Ms. Alicia Shepard
HydroGeoLogic, Inc.
SERDP Support

Mr. Bradley Smith
SERDP Program Office

Mr. Peter Swiderek
U.S. Army Infantry Center

Mr. Craig Ten Brink
Marine Corps Base Camp Lejeune

Mr. John Townson
Marine Corps Base Camp Lejeune

Mr. Chuck Van Horne
Marine Corps Base Camp Lejeune

Dr. Jeffrey Walters
Virginia Polytechnic Institute
Department of Biology

Dr. Joan Walker
USDA FS - Southern Research Station
Department of Forest Resources

Ms. Susan Walsh
HydroGeoLogic, Inc.
SERDP Support

Dr. John Wells
University of North Carolina
at Chapel Hill
Institute of Marine Sciences

Ms. Loretta Wright
Marine Corps Base Camp Lejeune

Appendix 3: Research Priorities by Breakout Group

In their original instructions, workshop participants were asked to develop a prioritized list of research needs for Camp Lejeune and the New River watershed. For organizational reasons, the body of this document (Section 3) omits priorities, capturing research objectives by category instead. The following lists reiterate, by priority, the research needs identified by participants.

1.0 AQUATIC HABITAT

While the Aquatic Habitat breakout group organized its recommendations for further research both spatially and temporally, crossover was significant; hence, the recommendations are presented below by issue. Prioritization was determined based on timeliness and level of impact.

1.1 Tier 1 – High Priority

Nutrients, Particulates, Contaminants, Pathogens

- For base-planning purposes (e.g., development of INRMPs), determine the ecological impacts of episodic versus chronic inputs of these constituents. Specifically, investigate the roles of varying frequencies of disturbance, storm water dynamics, and impermeable surfaces and buffers.
- Assess the impact of land use and training practices (e.g., burning, clear-cutting, buffers, ditching, channelization, salt marsh creation, live firing, amphibious traffic) on the input, transport, and fate of these constituents.
- Prior to the development of response parameters, determine the impacts of changes in the input and cycling of these constituents to the composition and activity of the microalgal and higher plant communities as well as the higher trophic levels. In doing so, community and species level indicators (e.g., HABs) should be applied.
- Evaluate the impacts of changes in ecosystem management practices on the input, transport, and fate of these constituents for base-planning purposes.
- Assess contaminants (e.g., perchlorate, PAHs, heavy metals) and their cycling, including toxicology for key plant and animal indicator organisms (e.g., oyster/mussel watch), to support compliance and respond to public concerns.
- Research physical/chemical/biological coupling in terms of residence time and bathymetry – productivity, community composition, and spatial distribution.
- Determine the exchange and mass balance of these constituents between the New River, coastal ocean, and atmosphere over time. From this information, establish a baseline and develop metrics for the monitoring plan.

Indicators

- Develop and apply indices of biodiversity and abundance to measuring changes in the food web and community structure.

Thresholds

- Establish thresholds (e.g., TMDL values, fundamental state changes) for physical, chemical, and biotic drivers of change (e.g., burning, runoff, resuspension) in support of compliance with environmental regulations.

Threatened, Endangered, and At-Risk Species

- Continue efforts to address threatened, endangered, and at-risk species and their habitats with an emphasis on holistic management.

Physical Disturbance Processes

- Investigate physical disturbance processes (e.g., storms/wind, beach nourishment, erosion, and vehicular traffic) in the context of natural sediment dynamics to understand habitat consequences (for benthos and vertebrates) and beach structure.

Hydrodynamics

- Conduct fundamental research to assess the relation of external inputs (surface, subsurface, and atmospheric) and stressors to internal biogeochemical cycling and sediment/water column interactions.

Climate Change

- Assess the direct and indirect effects of climate change (e.g., sea level rise) on ecosystem structure and function as a long-term priority.

1.2 TIER 2 – SECONDARY PRIORITY

Indicators

- Couple biological and physical-chemical indicators with remote sensing to facilitate ecosystem-level assessments of condition and change.

Hydrodynamics

- Assess the long-term impact of local and regional water withdrawal on the freshwater budget and associated effects on ecosystem.

Invasive Species

- Investigate the distribution, rates, effects, and management responses to exotic and/or invasive species (e.g., phragmites, harmful algal blooms).

1.3 TIER 3 – LOW PRIORITY

Hydrodynamics

- Investigate the impacts of dredging and channelization on sediment transport and hydrodynamics.

2.0 WATER QUALITY

The water quality breakout group subtitled their session “Impacts of encroachment and land use on water quality: where to and where not to develop.”

2.1 TIER 1 – HIGH PRIORITY

Improving Water Quality

- Identify areas where the installation can reap the best benefit for dollar spent.
- Systematically assess ongoing water quality conditions throughout New River tributaries, and analyze relevant impacts to identify where water quality might best be improved.
- Collect epidemiological information and conduct controlled research on swimming in, and shellfish consumption from, the New River and its tributaries.

Training

- Determine the relationship between water quality and training.
- Quantify impacts from sedimentation, especially in heavy troop movement areas.
- Develop **indicators** for impacts of base management activity on water quality, and establish metrics to measure the effectiveness of those efforts.
- Assess existing Camp Lejeune river and wetland conditions to evaluate impacts from installation management activities.

Sediments, Nutrients, and Pollution

- Examine point source and non-point source pollution via land use design/siting. Need more sustainable land use design to improve water quality.
- Examine nitrogen loading and nitrate input pulses entering the New River system following the activation of the new water treatment plant.
- Assess upstream and tributary contaminant contributions resulting in eutrophication problems within the New River watershed to better allocate resource.

Sediment Dynamics

- Conduct a source assessment and develop a management effort for these source pulses.
- Develop indices to understand sediment and nutrient pulses and their transport at the watershed and sub-watershed levels. Apply existing models for transport fate.
- Examine the role of sediments and impacts on oxygen dynamics (note: could use live and historic data collections to determine current patterns, chemical loads, etc.)

Land to water interface

- Develop **indicators** for tracking bacterial and microbial source perturbations of sanitary significance (e.g., viruses, pesticides, contaminations) and their fate.

Tidal creeks

- Identify and characterize affected/degraded tidal creek sites and related restoration options.

Comprehensive Assessment of Base Activities on Coastal Ecosystem

- Compile information on the coastal system to include both the beach and behind the beach (e.g., marshes) to quantify existing water quality (e.g., bacterial contamination).
- Examine erosion and sea level rise related to and resulting from training activities and management regimes (e.g., controlled burns).

Modeling

- Investigate the use of models to better understand water quality and system processes, beginning with hydrology and biology, nutrients, chemistry, tides, wind, etc. Types of models and outputs that might be beneficial include hydrodynamic models (where nutrients start and how long it takes them to move through the system).
- Investigate the hydrographic structure and how that structure is affected by meteorological and tidal events.
- Conduct probabilistic work to identify what areas of the base are more/less susceptible to potential nutrient loading/problems.
- Using a staggered/phased long-term approach, test alternative land use and military training scenarios.

Biological Body Burdens

- Investigate the potential for using shellfish, crab, and bottom-feeding fish as **indicators** of biological system health, in terms of ecological health and human impacts, in open vs. closed (i.e., training) areas.
- Apply aerial photography, GIS packaging/models (i.e., to demonstrate change in overall landcover/extent), and the available 30 years of Landsat to understand the status of phytoplankton. Use historical data on the identification and ecology of bloom forming algal species, especially in primary nursery areas.
- Use Landsat imagery to examine relation to training and land use over

Ground Water

- Determine the total quantity, source quantities, and recharge rates of base groundwater.
- Evaluate the hydrodynamic contributions of contamination loading to the river.
- Explore potential granular activated carbon (GAC) treatment options.
- Articulate trihalomethanes (THM) treatment concerns (e.g., fresh water has high THM).

2.2 TIER 2 – SECONDARY PRIORITY

The Water Quality group considered Tier 2 projects to be high priority, but felt they must necessarily occur at a later date. The ranking as Tier 2 therefore reflects a basis of chronology rather than importance. In general, the group concluded that there is a strong need for pilot projects, especially those focused on non-point source pollution reduction and habitat restoration.

Projects

- Examine quantity and quality of on-site surface water.
- Examine sediments in the estuary, focusing especially on presence of toxins or heavy metal loads in sediments.[13]
- Investigate the role of light and nutrient interaction.
- Examine nutrient loads that co-occur with sediments, accretion of sediments in shallow water habitats, and potential impact on nitrogen cycling.
- Examine soil compaction at the land/water (sea) interface, conducting systematic assessments of the impacts at training interfaces (e.g., from landing amphibious assault vehicles).

---

[13] Breakout group noted existence of an existing SERDP proposal to address this type of issue.

Watershed Source Identification

- Identify with confidence source(s) of pollution and contamination, keeping in mind that most benefit could come from conducting monitoring and management upstream. If proved, investigate potential to partner with City.
- Examine stormwater runoff impacts in urbanized and upstream areas.
- Identify microbial non-point sources (note: appropriate tools may not yet be fully developed).

2.3 TIER 3 – LOW PRIORITY

Contaminants

- Collect epidemiological information and conduct controlled research on swimming and shellfish consumption at Camp Lejeune.
- Measure seagull perching in recreational beach areas or in areas where there is training in water to help minimize and avoid bacterial risks.

Submerged Aquatic Vegetation in the Estuary

- Map existing SAV beds, and investigate bed expansion potential keeping in mind wave action, troop maneuvers, and other relevant factors.
- Determine impacts to SAV from new amphibious vehicles (e.g., on eel grass), and investigate whether these impacts were examined by the companies that created/designed the machines.
- Determine impacts to SAV from new weapons systems on SAV from White Oak to New River.
- Examine changes in nutrient conditions and how those changes may increase zostera.

Prescribed Burns

- Examine the impacts of conducting prescribed burns on streams and creeks.
- Determine if dioxin release is an issue of concern and/or if dioxin is released into waterways or ground/surface water during prescribed burns.

Other Research Ideas

- Examine potential for artificial fish to serve as environmental sentinels.
- Explore New River and tributary oxygen dynamics and hydro/geomorphology.
- Use models to determine the projected impacts of opening the inlet and increasing water flow.

3.0 TERRESTRIAL

3.1 TIER 1 – HIGH PRIORITY

Longleaf Pine Management

- Determine the consequences or implications to other species within the biological community of managing for the RCW in LLP habitat.
- Quantify impacts from various degrees of fragmentation on LLP forest health.

Longleaf Pine Restoration/RCW Recovery

- Identify the most effective method of restoring LLP in a senescing loblolly dominated landscape while expanding RCW population.
- Quantify impacts of RCW and LLP management to other species within the ecosystem.
- Assess assorted management schemes to determine which best benefits RCW recovery (e.g., siting of forest stands).
- Determine the consequences to the hydrology and water table of replacing offsite pines with LLP.
- Quantify the measures of connectivity among RCW clusters.

Fire issues

- Compare and contrast various burning scenarios, including timing and intensity, to determine the most effective option(s).
- Determine the effects of fire on soils, habitats (e.g., wetlands, forest), and on sensitive and invasive species within those habitats.
- Investigate management alternatives to burning in the event of EPA burning restrictions.
- Examine and articulate the correlations between prescribed burns and training usage.
- Examine the effects of wildfire and the effectiveness of prescribed burns, and correlate these impacts to the extent of area burned.

Disturbance issues

- Evaluate how various ecosystems respond to both short-term and long-term human disturbances.
- Investigate how varying degrees and distribution of disturbance, including from training, affect plant and animal species.

Coastal Region

- Explore various management techniques, comparing each to the other and to a non-managed option, to develop the most effective strategy for enhancing barrier island system health.
- Determine what actions are necessary to maintain Onslow Beach, and the physical and biological consequences (e.g., to sea turtles) of the techniques used.
- Assess the long-term consequences of not renourishing the beach, alternatives to renourishing the beach (e.g., dune protection), and the effects of the different types of renourishment on predators in the surf zone in fisheries habitats.

Species and communities of concern

- Need to better understand the demography of species-at-risk, and the functions of Camp Lejeune's unique communities.

3.1 TIER 2 – SECONDARY PRIORITY

Tier 2 projects were considered nearly as high priority as Tier 1 projects, but designated Tier 2 since not all efforts could be considered Tier 1.

Landscape structure

- Investigate how connectivity of habitats affects plant and animal species populations, determine the affects on genetic variability in isolated species communities, and identify plant and animal species that would benefit from connectivity.
- Determine if there are regional strategies besides connectivity that would improve species diversity and sustainability.
- Identify genetic population structure.

Rehabilitation Technology

- Identify optimal rehabilitation strategies for highly disturbed lands.

3.3 TIER 3 – LOW PRIORITY

Biogeochemical cycles

- Explore the biogeochemical effects of current and proposed management activities in various ecosystems. For example:
  - Articulate the changes to carbon sequestration caused by changing a loblolly pine system to a LLP system.
  - Determine the influences of pocosin management on carbon and nutrient cycling.

Watershed Management

- Collect information on riparian buffer zones. For example, determine length of time needed for riparian vegetation to recover after a minor/major disturbance.
- Examine the effects of watershed management strategies on water quality and fisheries habitats.
- Determine how urban storm drainage affects water quality.

Disturbance issues

- Quantify the effects of hurricanes on the biological community.
- Determine if specific strategies are needed to manage forests in ways that reduce the impacts of natural disturbance. If such strategies are needed, develop effective ones.

Disturbance due to Training

- Develop a sampling regime to collect more data on the type, frequency, and intensity of training. Investigate the potential for using GIS/remote sensing to quantify this impact.

4.0 COASTAL MONITORING

Although not a research breakout group, the coastal monitoring breakout group also provided suggestions regarding the development and implementation of a monitoring system in the New River watershed. We add these in order not to lose potentially valuable suggestions/information.

- Implement a monitoring system to identify and track ambient water quality (including contaminants) and coastal property elements using real-time monitors where feasible.
- Establish a long-term monitoring system that uses commonly accepted measurement scales and techniques.

- Collect both baseline data and data yielding comparisons over time.
- Monitor acoustic climate via hydrophone-mounted buoys.
- Track the beach and sand dune profiles over time, particularly with respect to impacts from training and seasonal events (e.g., hurricanes).

Appendix 4: Camp Lejeune Integrated Operations Network (CLION) Information Paper

January 2004

Purpose. To provide an overview of Camp Lejeune's effort to develop an integrated operations network of sensors that provides critical security, safety, environmental, and acoustic information.

Overview. The Camp Lejeune Integrated Operations Network (CLION) is an aggressive project that intends to create a fully integrated and operational network of security, safety, meteorological, oceanographic, and acoustic/seismic sensors. CLION will incorporate the latest sensor, communications, and information management technologies to incrementally develop, test, install, and maintain a *fully automated system* that collects, processes, archives, and disseminates critical information to enhance security, safety, training & readiness, and environmental management.

CLION Objectives

- Enhance Military Operations and Training (e.g., air/ ground, amphibious, special ops, decision support)
- Improve Personnel, Property, and Equipment Security and Safety (e.g., Chemical/Biological/Radiation alerts, Meteorological and Oceanographic [METOC], and Wet Bulb Globe Temperature Index [WBGTI] warnings, riptide locations, search and rescue support)
- Provide Explosive Noise Predictions and assessments (community health and welfare)
- Support Environmental Management (e.g., flood predictions, beach erosion, endangered species, water quality monitoring)
- Support National Oceanic and Atmospheric Administration's (NOAA) nation wide sensor integration and data collection efforts.

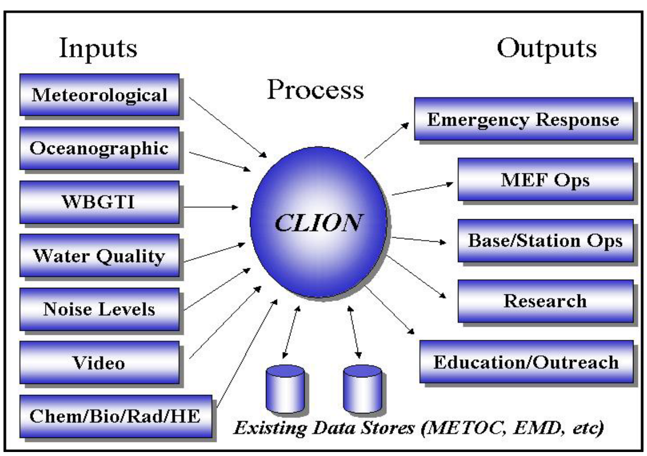


Figure 1. *CLION Input-Process-Output Chart. This is a diagram of input sensor groups and output categories of users.*

CLION Benefits

- Provides "near-real-time" products and alerts that will enhance security, protect equipment and *save lives*.
- Provides substantial monetary savings by consolidating the design, installation, and maintenance of all automated sensors aboard Camp Lejeune while improving access to this critical information.
- All units training aboard Camp Lejeune will have access to CLION products aimed at supporting commander assessments of environmental impacts on operations, training, and weapon systems.
- Supports destructive weather planners, search and rescue, mishap investigations, and disaster preparedness and recovery operations.
- Provides a noise management capability and supports environmental management and research objectives.
- Intends to provide access to data using a wide range of technologies such as; web portals, email, automated voice response systems, radio broadcasts, etc.

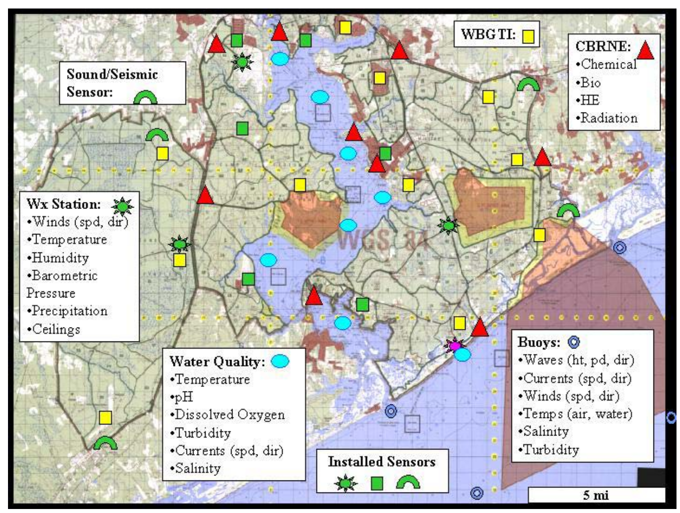


Figure 2. *Camp Lejeune Integrated Operations Network (CLION). This picture shows the current and planned sensors that will be integrated by the CLION project.*

CLION Development. CLION requirements are being developed utilizing a rigorous Information Technology Project Life Cycle Management (LCM) Process developed by Camp Lejeune. The sensors and management system will be incrementally designed, tested, and fielded as resources permit.

Point of Contact: **Mr Daniel Egge, Tech Branch, MCB Camp Lejeune, NC (910) 451-7567 eggedq@lejeune.usmc.mil.**